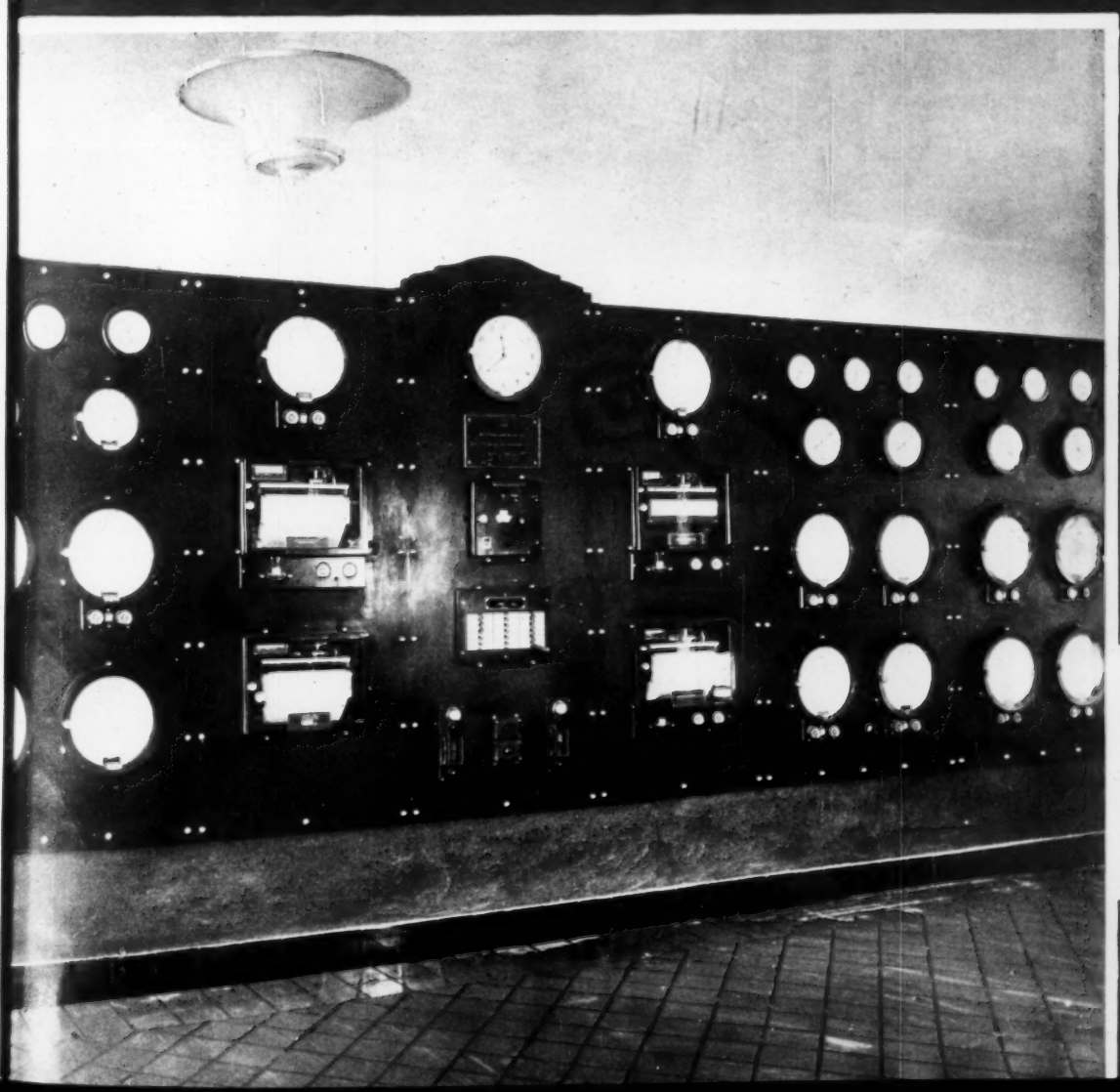
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT and CONTROL



VOLUME 10

FEBRUARY
1937

NUMBER 2

TAG's BIG CHARTS *are easier to* READ

Much is heard today about chart size, but TAG Recorder Design provides **the longest pen travel—4 3/4 inches**—on a full size 12-inch chart . . . the longest on the market. With characteristic thoroughness TAG provides this important detail to give you a chart with much wider graduations for each degree interval. Wherever Temperature, Pressure, Level or Flow must be recorded, TAG's BIG CHARTS give you easier reading.

Other features of TAG's new Rectangular Case Recorders are: interchangeable calibrated tube systems, over-range protection with safety linkage between Bourdon spring and pen movement, visible-record pen arm and new quick change famous steel chart hub.

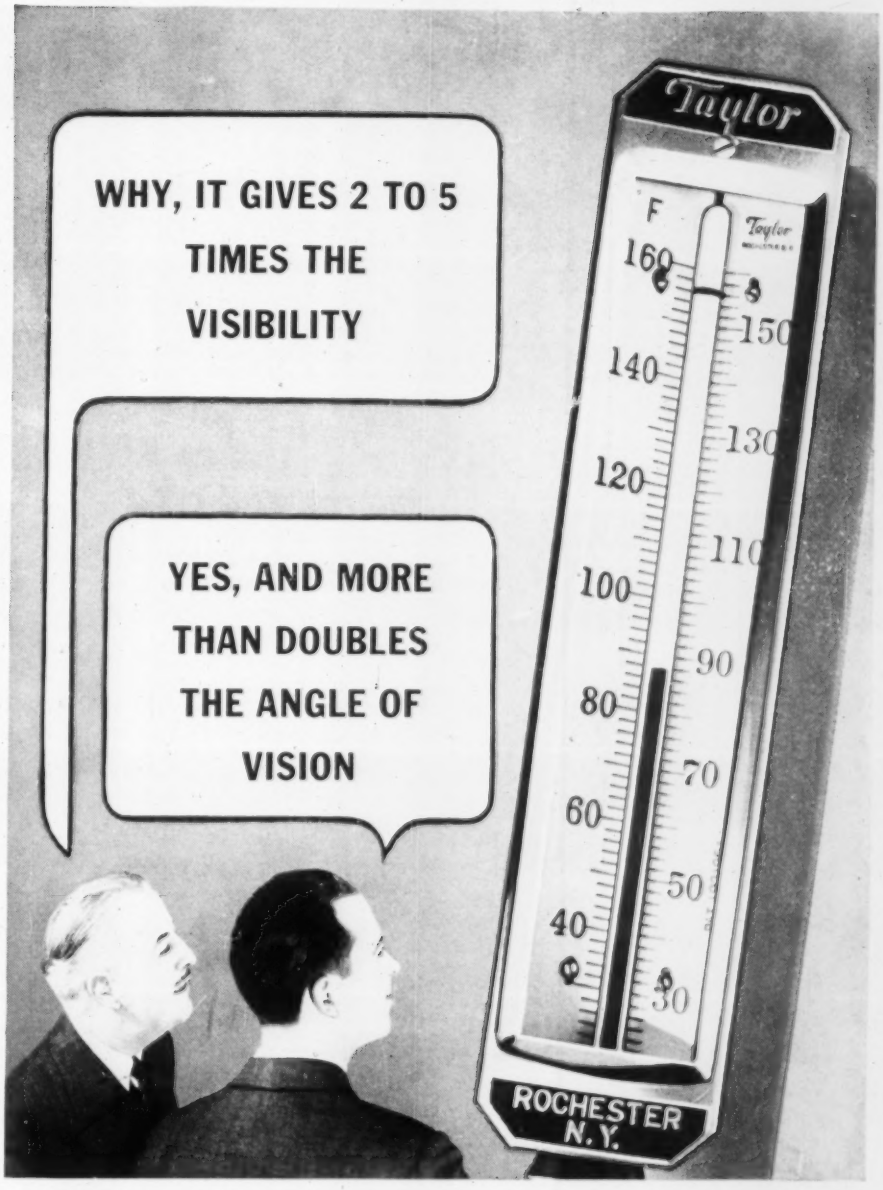
Behind these advancing instrument improvements, stands a long growing record of economical performance and dependable accuracy. Their steady rise to wide popularity recommends these newest of TAG Recorders to the duty of recording temperatures throughout industry.

We invite your inquiry concerning the application of TAG Recorders to your process

C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

They are talking about the new Taylor "BINOC" Thermometer Tubing — the optically correct tubing that makes Taylor Thermometers easier to read than ever before.



THE WORDS in the headline are not ours. They are expressions of amazement from the lips of people who have seen what they termed "a really big development" in the new Taylor "BINOC" Tubing.

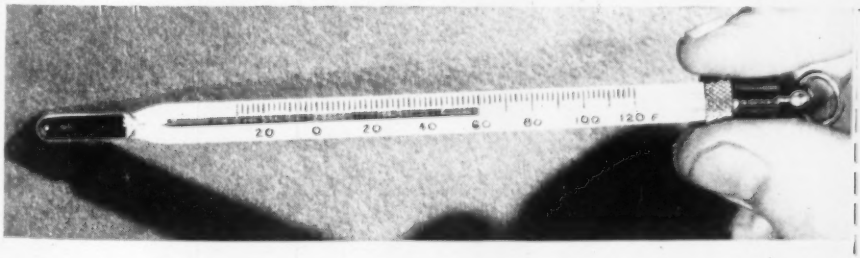
Behind all these words stands one of the first outstanding advances in thermometer construction in years. Taylor Engineers felt that "BINOC" Tubing with its triple lens construction, its greatly increased background for reflecting more light, its elimination of bore reflection, would provide the advantages that have been missing in industrial thermometers to date.

They were right. Today, "BINOC" Tubing makes Taylor Thermometers much easier to use. It gives greater visibility and readability. It greatly increases the angle of vision within which readings can be made. And does it without sacrificing high magnification.

How often in taking a reading of temperature as you pass a thermometer have you had to retrace your steps . . . stand directly in front of the thermometer . . . close to it in order to make sure you had seen correctly? With Taylor "BINOC" Tubing, you can catch the reading with greater ease and accuracy. You do not have to stand squarely in front of the thermometer. You do not have to stand so close to it.

Tests quickly prove the distinctive features of "BINOC" Tubings, tests that you can make yourself. A Taylor Representative will help you. Taylor Instrument Companies, Rochester, N.Y., or Toronto, Canada.

Taylor
INDUSTRIAL THERMOMETERS
with "BINOC" tubing
REG. U. S. PAT. OFF.



TEST "BINOC" IN YOUR OWN THERMOMETER

BE ONE of the first to get this New Taylor Engineer's Pocket Test Thermometer with "BINOC" Tubing. It is offered to you to make your own easy-reading tests. You'll find it convenient to use in scores of places. Ranges 0° to 220° F. or −30° to 120° F. Fill out coupon and order the range you want. Send check or money order.

TAYLOR INSTRUMENT COMPANIES
Dept. H-6, Industrial Sales, Rochester, N. Y.

I want to see "BINOC" Tubing. I enclose check for the new Engineer's Pocket Test Thermometer (with protective case).

CHECK HERE
☐ WITH RANGE −30° to 120° F.—$1.25 EACH
☐ WITH RANGE 0° to 220° F.—$1.50 EACH

Name _____

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

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NSTRUMENTS The Magazine of
MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

PARTICIPATE!

IF this admonitory title has not deterred you from reading this column, you undoubtedly belong to the staunchest sector of *Instruments'* circle of friends and enjoy our suggestions. Instead of suggesting anything, however, we shall describe the situation with regard to subscriber participation, split up into its elements:

1. *Readers at Work:* Excessive modesty on the part of six old subscribers caused that department to be left out of this issue. We had decided that the next few sketches would be of subscribers outside Pittsburgh, so we interviewed six in four States, but at the last moment all declined to see themselves in print!

P.S. We particularly desire (for your sake) to write up subscribers in industries which have not yet been covered by the Readers at Work Page, specifically aircraft, automotive, canning, cement, ceramics, drugs, lumber, paint & varnish, paper, rubber, sugar, textile, waterworks.

P.S. No. 2. Readers at Work is not a "Hall of Fame." Its only purpose is what its name implies.

2. *Feature articles:* We have a stack of manuscripts, all interesting, but are still waiting for you to describe that recent *process-control* installation.

3. *Instrumentation Forum:* This started out to be an almost spectacular success. Strange to report, however, not one solution of Problem No. 3 (page 27, last issue) has yet come in, so we extend the time to March 1.

As to problem No. 2, we sent the solutions to the consulting engineer who had consulted us and offered one extra $10 in addition to all our $5 prizes; and have just received his reply:

I have looked over the various solutions shown on the galley proof you sent me.

The solutions involving measuring of the electrical resistance or of the dielectric constant—those offered by Ewald, Kettenring, Tozier, and Wenger's No. 2—are unacceptable because they disregard the variable ash content which affects these measurements.

Brevoort's method suggesting the measurement of the heat of dilution of the dissolved sample is impractical because of the slowness of the dissolving process. His suggestion "to measure plasticity is, because of the small changes in plasticity with large changes in moisture content, too uncertain. Small differences in quality apparently affect plasticity more than changes of the water content in certain moisture ranges." The rebound test is also out due to the flat lentil-like shape of the material. Nor is the extrusion method practical for the above stated reason as well as the pronounced effect small temperature changes have on plasticity.

Wenger's No. 1 solution is unsatisfactory because of the varying ash content. His No. 3 solution applies only to a limited moisture range, above and below which the variations are considerable and defy determination of a specific relationship even for samples of the same material.

I am much interested in the solution given by Olken. I consider it entirely possible that an instrument of that type will yield the desired results, but would like to know more about it. If you can furnish this information I shall be grateful. If this method is the answer to the problem I shall be only too glad to name it the special prize.

4. *Questions and Answers:* The $1.00 offered for each supplementary answer probably seems little in comparison with the Forum Department's $5.00; only one has been received. We feel certain that our own answers are imperfect and incomplete—simply crying for supplements and complements!

IN THIS ISSUE

Dr. Williams, in the second instalment of his serial, gets right down to the atomic and grain arrangements that have a bearing on hardness.

Complying with requests for articles on how to use electron tubes for industrial measurement and control applications, we take pleasure in printing one on the industrial applications of the grid-controlled gas-filled rectifying variety, by R. K. Gessford, who is a specialist in this class of work.

Ralph Batcher continues to describe practical applications of cathode-ray tubes; this month he takes up magnetic tests.

To this month's instalment of our Electrical Measurements and Control serial, Perry Borden contributes a rich selection of examples showing what electromagnetic oscillographs can do.

Thirty "New Instruments" Department items this month—and some items describe two, three or several new devices.

THE FRONT COVER photograph does not show all the panels of the control board at the Southport Petroleum Co., Texas City, Texas, but this diagram does, and the Brown Instrument Co. informs us that the instruments are: (1) indicating pressure gages, (2) pressure recorder, (3) pressure recorders with air-operated control systems, (4) electric flowmeters with air-operated

control systems, (5) recording thermometer, (6) recording thermometers with air-operated control systems, (7) recording potentiometer pyrometer, (8) potentiometers with air-operated control systems, (9, 10) indicating potentiometer and switch for supervising temperature, (11) clock, (12) signals, etc. This job was engineered by the Mid-Continent Engineering Corp., Dallas, Texas. The panel material is ebony asbestos.

Atlantic Steel Company, Atlanta, Georgia, use their Riehle Precision Hydraulic Testing machine for all physical tests in their mill. Wire, angles, hoops, reinforcing bars, rail, billet steel and flats are tested —loads running to the 200,000 pounds limit of the machine and wire tests as low as 1,000 pounds.

"It is as good a machine as I have ever seen," says C. J. Blackmon, Chief Inspector. "Fool-proof, with an accuracy well under the guaranteed 1% margin of error. It is so sensitive that it responds to the tremors of passing cars and even the weight of a specimen or tools on the table. We have never experienced a minute's mechanical trouble."

There are no springs, no levers in the Riehle Precision Hydraulic. And no recalibrations are necessary. Write for folder describing this machine.

RIEHLE DIVISION

American Machine and Metals, Inc.

100 Sixth Avenue, New York, N. Y.

"One Test is Worth a Thousand Expert Opinions"

RIEHLE DIVISION

NEW INSTRUMENTS

In this department we strive to report each month ALL the new de s for measurement, inspection, testing, metering and automatic contro n the form of concise technical descriptions.

When writing to manufacturers directly, please mention this departmen as your source of information.

Or write to Information Section, Instruments Publishing Company.

Multi-pointer Gage

In this new diaphragm type multi-pointer gage, developed for boiler-room service, the diaphragm material is resistant to oil, acid, caustic and heat, and is said to possess exceptional flexibility. Each measuring unit (Fig. 2) consists essentially of a flat calibrated spring, a sealed link, and a power diaphragm the weight of which is carried on a second link pivoted at one end on the calibrated spring and at the other end on the sealed link. Draft on the left side of the diaphragm causes movement of the system to the left. Motion, opposed by calibrated spring, is transmitted by sealed link to outside of diaphragm unit where a drive link carries motion to pointer. For indication of pressure the connection is made on the opposite side of the diaphragm; for differential pressure, connections are made to both sides. Diaphragm area is 20 in.^{2}. Diaphragms may be removed and replaced or interchanged without returning the unit to the factory and without danger of wrinkling. Zero adjusting screw may be turned from outside gage casing by means of an adjusting key. Stops at both ends of diaphragm drive and support link prevent damage of pointer by over-deflection. Diaphragm is unharmed by excessive drafts or pressures sometimes encountered in boiler operation. Gages are available in casings containing from one to twelve units; may be surface, semi-flush, or full flush mounted. *Bailey Meter Co., 1071 Ivanhoe Rd., Cleveland, Ohio.*

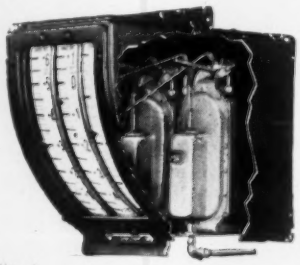


Fig. 1

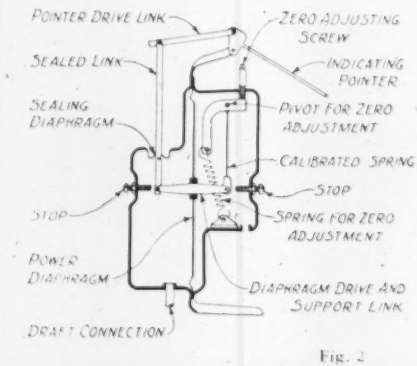
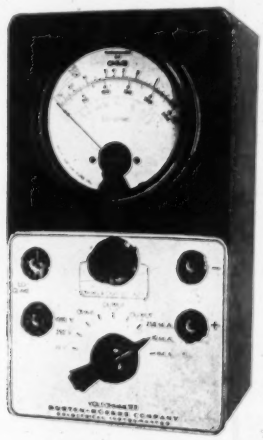


Fig. 2

Radio Set Multimeter

Designed for radio service, laboratory and production men, this new compact volt-ohmmeter, milliammeter and output meter fits into the pocket and may be used for practically all receiver chassis measurements right on the job. It has a d'Arsonval movement with 3" dial with two-color scale, knife-edge pointer and zero adjuster. The d-c. milliampere scale reads 0-1, 0-10 and 0-250. Two output scales are provided, one for the voice coil circuit, the other has a blocking condenser. The two ohm scales are direct reading: ½ to 500, and 200 to 500,000. *Burton-Rogers Co., 755 Boylston St., Boston, Mass.*

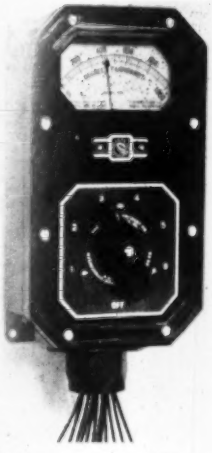


Thermostatic Trimetal

"Tri-ply Metal" has been developed for applications requiring smooth and uniform motion of free end of element, within extremes of 0°F. and 1200°F., in dry air, in a humid atmosphere, or even immersed bare in water. It consists of three layers, the outer ones ("1" and "2") of approximately equal thickness, and the middle one ("3") relatively thin; approximately one-fourth as thick as "1" or "2." Elements are available in strip form or in any shape. Materials are reported to be: "1—Active Metal, 22% nickel steel; 2—Highly Active Metal, copper alloy; 3—Inactive Metal, 36% to 42% nickel steel." Manufacturer describes operation as follows: "When heat or cold is applied to Tri-ply the third [inner] element (3) is the first to respond and functions thermostatically with the active metal side (1) and physically against the inactive metal (2) causing the entire strip to move in an arc. A new method of combining the three metals assures them from ever separating under the most severe conditions." *Laminated Metals Corp., 225-283 Eddy St., Providence, R. I.*

Diesel Engine Pyrometer

Designed especially for Diesel engine use, a new pyrometer is available in three temperature ranges: 0-1000°F., 0-1200°F. and 0-1600°F. and with 4, 6, 8, 12, 16 or 24 switch points. The 0-1000°F. range instrument is also available with "cold," "normal" and "danger" operating zones plainly indicated on the scale. Vibration resisting qualities, extreme ruggedness and light weight are claimed. Measuring system is provided with a special neutralizer having a negative temperature coefficient, permitting use of relatively heavy springs in the system while still maintaining a low overall temperature coefficient. Case is of light-weight molded Bakelite, permanent finish, water-proof. A dial type switch, integral with pyrometer, is mounted in a separate compartment of the pyrometer case. Switch points are said to be extra large. Elimination of terminal board has promoted compactness: Leads (20" long) are brought from switch points through a pipe fitting in bottom of the box. This construction permits use of a junction box at a vibrationless remote point. Pipe fitting is suitable for back or bottom connections. Enameled metal scale is 3⅛" wide, printed in black and white. Each pyrometer is calibrated within 1% of full range in the normal operating zone and within 2% outside that zone, is available for use with Brown IC Thermocouples. *The Brown Instrument Co., 4782 Wayne Ave., Philadelphia, Pa.*



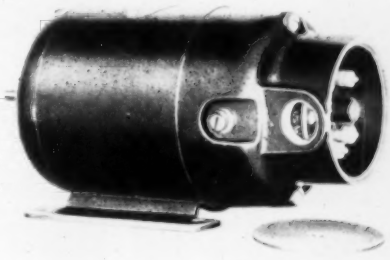
"Four-in-one" Watch

Name is derived from functions: (1) Timepiece of the wrist-watch form with 7 jewel movement in chrome-steel back case and with sweat-proof strap; (2)

Stop-watch which measures seconds and fifths, has 60-minute register permitting timing during one hour period; (3) "Tachometer" indicating miles-per-hour over known distance; (4) "Telemeter" which gives distance by interval between light and sound from simultaneous source. *Pierce Watch Co., 22 W. 48th St., New York City.*

Position-type Motor for Telemetering, etc.

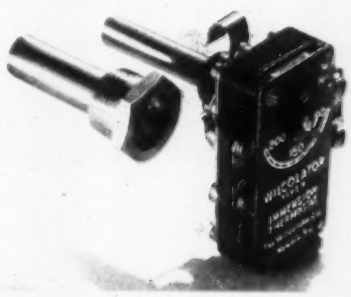
On 60-cycle power this new "Selsyn" device will give a safe operating torque of 12 in.-oz. at 25° displacement, and a maximum synchronizing torque (pull-out or pull-in) of 65 in.-oz. at 110° displacement. Accuracy ±5°. Either primary or secondary can be wound for up to 250



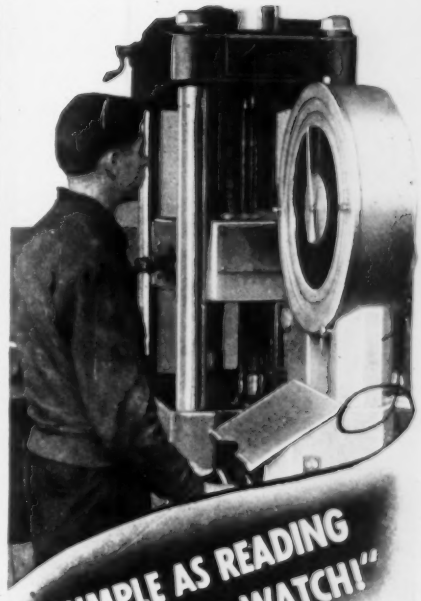
volts on 25- to 60-cycle power. The new unit measures approx. 8¾" × 4" × 4". It has a welded frame shell and stainless-steel collector rings. Shielded ball bearings are normally used; special grease-packed bearings can be provided for use where continuous high-speed rotation is necessary. Installation is facilitated because design incorporates a completely-enclosed terminal board at the collector end. Provision is made for conduit connections to the flange, which houses the terminal board, and the brushes are accessible for inspection or replacement. *General Electric Co., Schenectady, N. Y.*

Immersion Thermostat

New Type T high-capacity immersion thermostat consists of a thermostat unit and a brass well. The well is provided with ¾" I.P.S. threads. The thermostat bulb fits into the well and a positive



mounting screws or brackets are necessary. Thermal element is of liquid-filled bulb and flexible bellows type, said to provide sensitive temperature control and spring lock holds it in position. No to be powerful in its mechanical action. Snap-action switch mechanism; large silver contacts. Thermostat will operate in any position so that it is unnecessary to level the appliance. Shaft can be extended so that adjustment can be secured from outside tank case if desired. Two models: Type T-1 double-pole, double-break with normally closed contacts; Type T-2 double-pole, double-break, one pole normally closed and the other pole normally open, designed for use with "off-peak" water heaters and appliances of this type. *The Wilcolator Co., 17-37 Nevada St., Newark, N. J.*



In the Riehle Precision Hydraulic Testing Machine, the ram is powered by a motor-driven oil pump and moves at a constant speed under control from a single hand wheel. The load indicator has a single dial. By adjustments to the Indicator pendulum arm, three scales are provided, one-tenth, one-half and full. All loads are read on the single dial. Two automatic safety power cut-offs, one controlled by the limit movement of the table and the other by the load limit of the machine, protect the unit completely against over-movement or overloading. A transverse table and transverse and bending tools provide for bending as well as tensile or compression tests. This table extends beyond the central table on extension arms at each end and permits tests of unusually long span. The load scale is quickly adjustable to compensate for the weight of the specimen and grips or other loads on the machine not caused by the test itself. The need for any compensation factors is therefore avoided.

RIEHLE DIVISION
American Machine and Metals, Inc.
100 Sixth Avenue, New York, N. Y.

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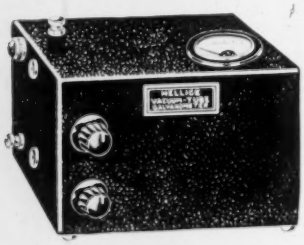
HELLIGE
GLASS ELECTRODE
pH-METER

READING DIRECT FROM 0 TO 14 pH

For All Types of Electrode Systems

The new Hellige glass electrode pH-Meter measures hydrogen ion concentrations and reads direct in pH units with all types of electrode systems, over the complete range of 0 to 14. The sensitivity is 0.02 pH and the working accuracy is 0.05 pH. Rugged — Portable — Applicable for titrations and as a separate null indicator.



VACUUM-TUBE GALVANOMETER

This instrument is a general purpose null indicator of universal adaptability for precise measurements of oxidation-reduction potentials, streaming potentials, insulation resistance, and various types of bridge measurements.

Suitable for measuring systems of high resistance (10^{19} ohms), and those easily polarized, with the same high sensitivity (0.1 millivolt) and the same simple technique as that of ordinary systems.

HELLIGE
INCORPORATED
3702 NORTHERN BLVD. LONG ISLAND CITY, N.Y.

Furnace Atmosphere Quality Recorder

"Furnace Atmosphere Analy-graph" has been produced after months of testing to determine most important measurable factors in furnace atmospheres. (Tests covered electric and fuel-fired furnaces, and a wide range of temperatures with varying air/gas ratio adjustments.) Recording instrument (Fig. 1) is of potentiometer type, with a 12" wide chart graduated so as to render equipment applicable to measure atmosphere quality whether atmosphere results from complete or incomplete combustion, or from dissociation. Equipment operates on thermal-conductivity principle, sample of gas mixture being continuously drawn

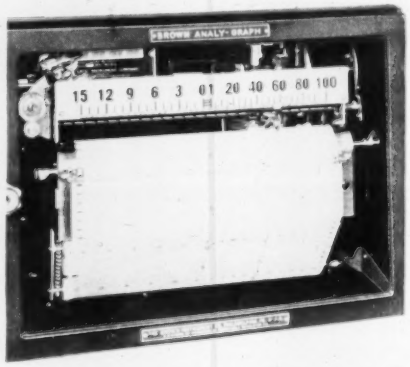


Fig. 1

from the furnace. Analysis equipment shown in Fig. 2. If gas is result of complete combustion, thermal conductivity will be less than 1.00 due to presence of CO_2; while if sample has been produced by incomplete combustion or by dissociation, thermal conductivity will nearly always be greater than 1.00 the only exception being when there is less than 1% combustible in the final p... In order to render instrument ... useful for measuring all types of ... spheres, chart has been divided in... equal sections: one section is use... combustion is complete; the othe...

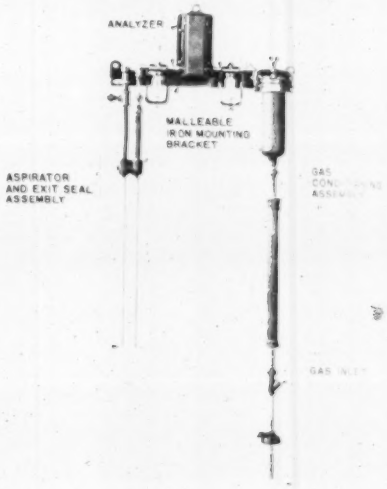
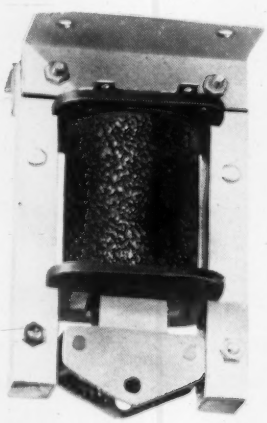


Fig. 2

combustion is incomplete. This is accomplished by using different electric sensitivities for the Wheatstone bridge through a patented feature. "Furnace Atmosphere Analy-graph" is said to be easily maintained, independent of normal variations in furnace pressure, room temperature, and humidity. Large scale permits operators to observe the condition of their furnace atmosphere at a distance. *The Brown Instrument Co., 4782 Wayne Ave., Philadelphia, Pa.*

Relays and Solenoids

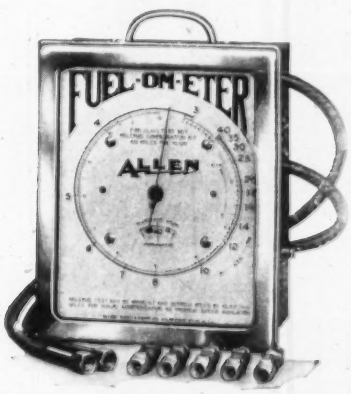
Extension of maker's line of a-c. and d-c. relays is announced, including models for industrial applications. Also announced is an enlarged line of solenoids including three regular series and a series of specials. Illustration shows



Series 3 for a.c. or d.c., with laminated core and plunger; operating range 24 to 220 volts d.c., 440 volts a.c.; power consumption 40 watts on d.c. and 60 watts on a.c.; 1½" plunger, ¾" stroke, 2-lb. pull.—*Guardian Electric Mfg. Co., 1621-27 W. Walnut St., Chicago, Ill.*

Automotive "Fuel-om-eter"

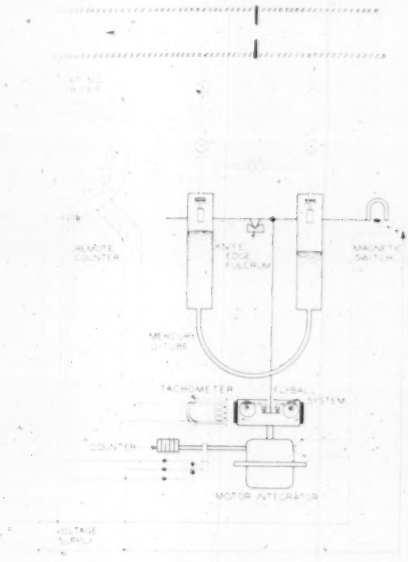
Purpose of new E-330 "Fuel-om-eter" is to check mileage obtained on passenger cars and light trucks at speeds of 30 to 60 m.p.h. and on heavy trucks at speeds of 10 to 30 m.p.h. It measures on a speedometer type dial the gasoline flow from the tank to the carburetor, and is said

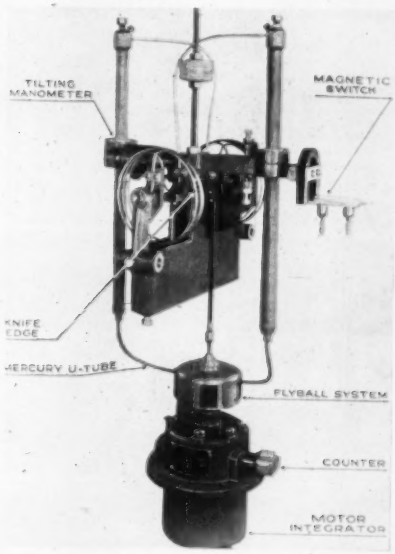


to show the consumption directly in miles per gallon. While but one scale is used, the consumption can also be measured in gallons per hour, and tenths of a gallon per hour, the latter being used for idling tests of importance to taxicab and fleet owners.—*Allen Electric & Equipment Co., Kalamazoo, Mich.*

Null-method Flow Measuring and Integrating Equipment

nouncement is made, as of Feb. 1, of commercial availability of "Cen- Flow Meter," which has, however, in steam plant service for water rements for more than two years.

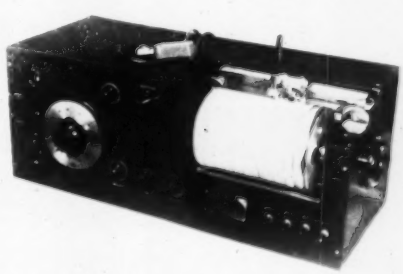




It therefore is new only in that maker now releases publicity; but also in that it is the first flow-rate measuring system and flow-quantity registering system employing the null method. Schematic diagram shows primary element of the orifice type, but any other differential-producer may be used which gives a square-root relation of flow to differential. Manometer, of U-tube form, is supported on a knife-edge. Measurement of differential is not accomplished by deflection ("tilting manometer" principle) but by opposition of a mechanical force automatically varied to restore balance whenever value of differential changes. This force is exerted by a fly-ball system driven by an electric motor. It is proportional to the square of the motor speed. Since the two square-root relations cancel, motor speed is proportional to flow rate, and no rectifying devices are needed. Since motor is of ample power, friction and other effects simply load it more, without introducing sources of error. Since measurements of motor speed and counts of motor revolutions can both be telemetered electrically with a high degree of accuracy, remote indications and records of flow-rate, as well as remote integration of flow-quantity, are subject to negligible errors. Series of tests against standard water manometer (for flow-rate) and against standard tank (for flow-quantity) were made under conditions involving variations in frequency, voltage, temperature, etc., as encountered in plant service, and showed errors sufficiently small to enable maker to make following guarantee: "width of wedge of error of integration ±0.5% of actual flow at 100% flow and ±1% of actual flow at 25% flow . . . exclusive of primary element error which, when known, can be compensated by adjustment of the balance." Maker's own indicating and recording instruments, of square- or round-case models, are embodied in "Centrimax" system; counters and other such parts are of standardized models and makes. *Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.*

Autographic Audio-frequency Analyzer

A self-contained a-c.-operated instrument for producing automatically a graphic record of the audio-frequency characteristics of receivers, a-f. amplifiers, audio filters, loud-speakers, transformers, microphones or audio-pick-up devices, marketed under the trade name Model 15-D Audi-O-Graph, comprises the following: (1) A beat frequency oscillator delivering a continuously variable a-f. voltage for application directly to an a-f. system or for modulation of the 1,000-kc. carrier developed by an auxiliary r-f. oscillator also incorporated. (2) A calibrated standard crystal microphone for picking up sound waves and a means of connecting the input of the recorder to any portion of the audio system under test if the microphone is not used. (3) A suitable a-f. amplifier to insure ample voltage for operating the recorder. (4) A motor-actuated pen responding to changes in a-f. voltage. (5) A chart holder connected to the control shaft of the beat frequency oscillator. (6) Charts graduated in cycles per second *vs.* decibels. *Esterline-Angus Co., Inc., Indianapolis, Ind.*



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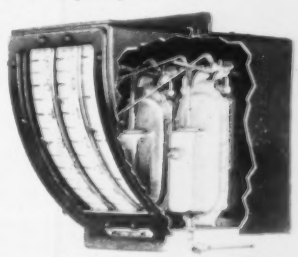
METERS and CONTROL *for Boiler Room Service . . .*

Boiler Meters Indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature. The use of this meter reduces fuel cost, lessens maintenance and outage, lowers standby costs, and adds capacity.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems. Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

Complete information on any of the above Bailey products will be gladly furnished upon request.

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New Copy
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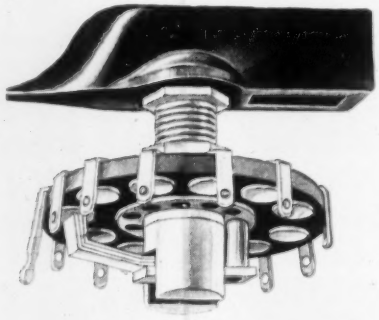
1144 EDDY ST. PROVIDENCE, R. I.

DETROIT CHICAGO MUNCIE
CLEVELAND NEW YORK

Instrument Switches

Two small rotary switches (a single-deck and a double-deck) are announced, regularly supplied with eleven (0-10 inclusive) contact points made of silver or brass as specified, but available with as many as sixty contact points on special order. Contact resistance is constant and its value is less than 0.0015 ohm; surface



leakage is minimized by employment of steatite and its value is about 10^{13} ohms. Construction is such that maker's Type 170, 180 or 190 wire-wound resistors may readily be mounted. Applications: decade boxes, thermocouple banks, analyzers, etc. Each switch can be supplied with aluminum box, Bakelite cover and aluminum etched dial plate. *Shallcross Mfg. Co., Collingdale, Pa.*

Battery Tester

"Model E-180 Portostat" is equipped with four moving-coil instruments. The three voltmeters are scaled 0-2.5 and are marked DEAD, DISCHARGED, PARTLY CHARGED, and CHARGED. Three miniature lamp bulbs, one under each voltmeter, by their brilliancy assist in explaining the condi-

tion of the battery cells to car owners. The ammeter has a 0-300 scale, and an etched plate on the panel shows the proper discharge rate for all batteries. *Allen Electric & Equipment Company, Kalamazoo, Mich.*

Surface Temperatures

Flat Stationary or Moving Curved Surfaces

The "Alnor" Combination Pyrocon

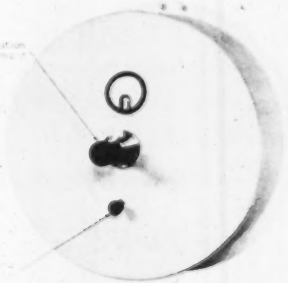
Ideal for rolls, molds, plates, platens and plastic material temperatures.

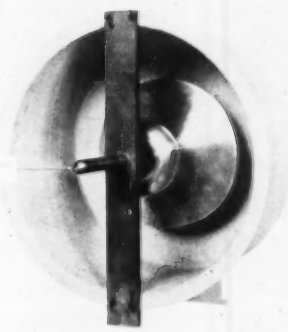
Write for bulletin.

Illinois Testing Laboratories, Inc.
142 W. Austin Ave. Chicago, Illinois

High-voltage High-frequency Voltmeter

A new design of high-frequency high-voltage voltmeter of the capacitor-potentiometer type is direct-reading over a frequency range of 20 to 100 kc and





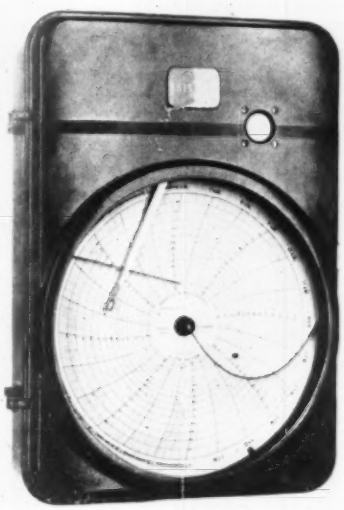
is calibrated for 10 to 50 kilovolts r.m.s. The current drawn is minimized by the low capacitance of the high-potential electrode, and the use of a guard provides assurance that only the current which flows through the actual capacitance between the plates (3 to 4 $\mu\mu$fds) is measured by the indicating instrument. *General Electric Co., Schenectady, N. Y.*

Constant-impedance Output Attenuator

Said to be capable of handling considerable power with low insertion loss, "Series CIA" output attenuator safely dissipates 25 watts continuously, regardless of setting, and has a minimum insertion loss of 1.3 db. Standard surge or input impedances available are 8, 15, 50, 200, 250 and 500 ohms. Other impedances available to order. Perforated metal case measures 4" long by 3¼" diam. Detent action switch selects the 16 attenuation values, linear up to 45 db, in steps of 3 db, with an end position of infinite attenuation. Impedance from load end is approx. three times line value. *Clarostat Mfg. Co., 285 N. 6th St., Brooklyn, N. Y.*

Electric Flow Meters

...dition of a complete line of electric ...eters for steam, liquids, and gases ...ker's line of mechanical flow me... announced. New meters employ ...meter" principle of telemetering (*Instruments*, Oct. 1932, page 244, 1935, page 23), can be furnished ...ording, integrating, and indicating Readings are transmitted over a



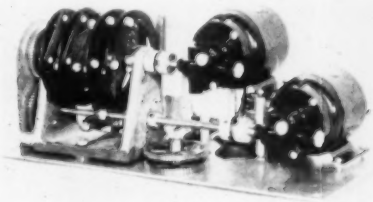
two-wire circuit, telephone circuits included, which does not enter into the calibration of the instruments. All electrical contacts are enclosed in glass. A standard Bristol meter body is employed to measure the differential across an orifice. Both transmitter and receiver are equipped with moisture-, fume-, and dust-proof aluminum alloy cases. Conduit openings are provided so that the instrument may be used with modern wiring systems. — *The Bristol Co., Waterbury, Conn.*

Multi-purpose Tester

Said to combine in one instrument the equivalent of 11 separate units, Multi-purpose Tester, Model 1504, checks any type tube for worth; Neon short test (for shorts and opens); separate diode test; metered paper condenser test; electrolytic condenser leakage test; d-c. voltmeter; d-c. milliammeter; a-c. voltmeter; ohmmeter; decibel meter; complete free-point tester. Tube testing is by power output emission method. Quartered oak case with sloping silver and black panel, for portable and counter use. Dimensions 15¾" × 11½" × 7½". — *The Triplett Electrical Instrument Co., Bluffton, Ohio.*

Speed-regulating Relay

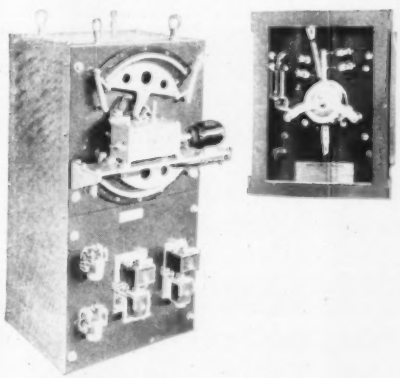
What is said to be an entirely new design of speed-regulating relay has been produced for maintaining a preset slow-down speed (as on a printing press, etc.), by controlling a contactor, which cuts resistance in and out of the secondary circuit of a wound-rotor motor. This new relay consists of two small motors mechanically coupled through a ratio-changing set of gears and a differential,



the frame of which carries the floating relay contacts. One motor operates at line frequency while the other is supplied at slip frequency from the main motor collector rings. — *General Electric Co., Schenectady, N. Y.*

Generator Voltage Regulator

A new line of larger rocking-contact voltage regulators, designated as "Type J," have been designed and developed for the control of large and important synchronous machines where high speed of voltage recovery, accurate voltage control and reliability are essential. In modified form they can also be obtained to control large d-c. generators. Design incorporates high-speed features as well as the rocking-contact principle used in



makers' existing lines of voltage regulators. The two main parts of the complete regulating equipment are (1) the voltage-control element, connected to the machine to be regulated through suitable potential transformers and operating its contacts when the voltage differs from the normal value; (2) the rocking-contact motor-operated rheostat which is the means for varying the machine field current and adjusting it to the correct value to give normal generator voltage by acting in the exciter field circuit. The major element of this equipment is the rheostat, constructed on a larger scale than employed in the standard regulators and providing a greater number of steps of higher current-carrying capacity. When voltage of synchronous machine is normal, entire regulating equipment is at a standstill, assuring minimum wear. — *Allis-Chalmers Mfg. Co., Milwaukee, Wis.*

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AUTOMATIC POLISHING MACHINE

Outstanding and New Features

1. Three or more specimens can be polished simultaneously.
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3. Specimens in bakelite mounts can be used.
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5. Continuous speed regulator permits changing from 350 to 1000 R.P.M. while machine is in action, retaining full strength of motor.
6. All parts are easily removable for cleaning. Changing the polishing disc requires only a few seconds.

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"Model C"—an Entirely New Potentiometer

The most rugged, most reliable and foolproof portable potentiometer ever built.

Its calibration is established by basic physical properties of elements. No standard cell or other chemical device subject to deterioration is employed to standardize it.

Accurate and reliable in the hands of the technician, safe from damage in the hands of the workman.

Completely self-contained; Size 6" x 7" x 4"; Weight four pounds; Beautifully finished molded Bakelite throughout.

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OVENS WATER BATHS
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The New "HS-4"

This is an ultra-sensitive, yet rugged temperature controller designed especially for ranges with upper limit of 150° C. or 300° F. Its adjustable range is 75° C. or 150° F., depending upon the active length of tube. *Operating differential 0.1° C.* Even under most difficult conditions a differential of 0.2° C. is obtained.

OTHER FEATURES

Hard Burloid contacts. Uniform performance. Operates in air or liquids. No glass to break or mercury to spill.

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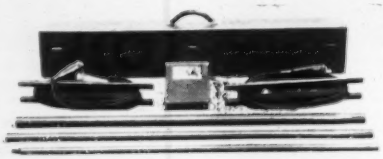
BURLING INSTRUMENT CO.

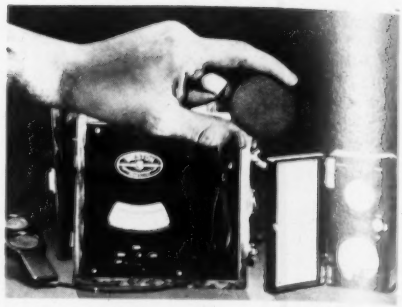
239-243 Springfield Ave., Newark, N. J.

Line Insulator Tester

Appearance of "Hipot" tester for string or pin type insulators brings into being a new method of testing in the field: periodic live-line testing of each individual insulator unit on the basis of percentage of total voltage from line to ground. Thus, for a string of insulators, all alike and all good, the gradient is such that the successive voltage values will lie on a smooth exponential curve.



A sharp break in the curve unmistakably denotes a defective unit and an irregularity denotes a suspicious unit, so that operator need not be skilled. Outfit (portable) comprises a sectional test stick, an indicating instrument, a ground prod and the necessary connecting cable and connectors. Test stick consists of three insulator sections and one grounded-shielded handle section, screwing into one another like a fishing pole. Insulation value being about the same as that of the wood stick used to open disconnects, test stick can be used with absolute safety even if handle shield is ungrounded: for example, if ground connection is suddenly broken while tip of stick touches a 132-kv. line, operator feels a slight static discharge. Indicating instrument is self-contained with its coupling transformer and adjusting rheostat in a 6" square by 3" deep steel case, the back of which carries a threaded support for the ground prod. To set up outfit, stick is assembled and connectors are plugged in, sharp-pointed prod on which instrument is mounted is shoved into ground, and rheostat is adjusted to make instrument read "100" when live line is touched above first insulator. To make a test, metal collars between insulators are successively touched and each instrument reading recorded (on a printed form or on any cross-ruled paper). — *Roller-Smith Co., 2132 Woolworth Bldg., New York City.*

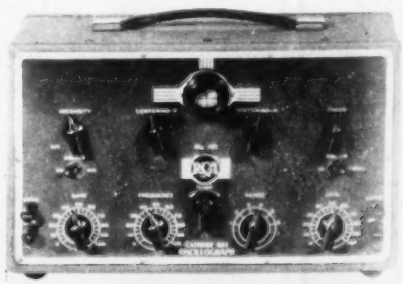


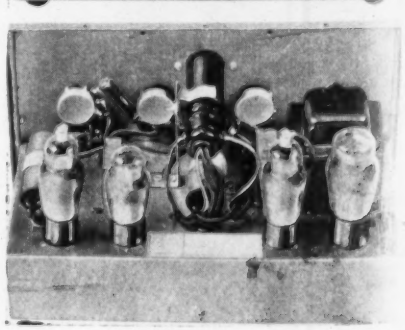
Filter for Photronic Cells

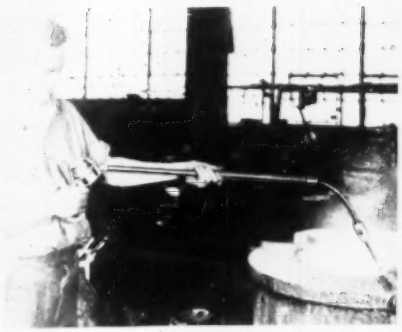
Known as "Viscor" (visual correction), a glass filter which brings the spectral response of the Photronic photoelectric cell into close agreement with that of the human eye has been brought out for photometric work based on the I.C.I. Standard eye sensitivity curve, particularly with monochromatic light and other light sources whose output the eye has difficulty in comparing by using the ordinary photometric methods. It is intended for use with direct-reading photometric intruments in which a Photronic cell converts light energy to electrical energy. While the unfiltered cell responds throughout the entire visible spectrum, it also is affected to some extent by radiant energy in the ultra-violet and near-infra-red regions and is more sensitive in its blue and green regions than the eye. Use of the new filter over the cell maintains cell response proportional to eye response at any wavelength or combination of wavelengths. Approximate accuracy at normal incidence: Tungsten (2360°-3260° K.) ±2%; any continuous light source (daylight, filtered tungsten, etc.) ±3.5%; commercial monochromatic sources (sodium, neon, mercury vapor, etc.) ±5%. The total transmission of the Viscor filter is approximately 37.5%, said to be high for a filter with complete cut-off at both ends of the visible spectrum. — *Weston Electrical Instrument Corp., 589 Frelinghuysen Ave., Newark, N. J.*

Cathode-ray Oscillograph

Designed for the specific purpose of permitting "additional thousands of service engineers" to enjoy the advantages of oscillographic testing at "almost half the cost" of larger instruments, new No. 151 Cathode-ray Oscillograph nevertheless includes a sufficient number of elements and of adjustments to qualify it as a "general-purpose" oscillograph for industrial applications. Its cathode-ray tube is the new RCA-913 with 4" screen, with sensitivity of 1.75 r.m.s. volts for full-scale deflection, with both focus and beam-centering controls and with calibration screen. There are vertical and horizontal amplifiers (gain 50) with individual controls, in a flat range of 30-10,000 cycles. Linear timing axis (horizontal sweep) employs an RCA-885 tube and its range is 30-10,000 cycles. Input power consumption is 50 watts cold, 80 watts hot. All controls on front panel. Dimensions 13¾" × 9¼" × 7¾". Weight 11 lbs. — *RCA Parts Division, RCA Mfg. Co., Inc., Camden, N. J.*





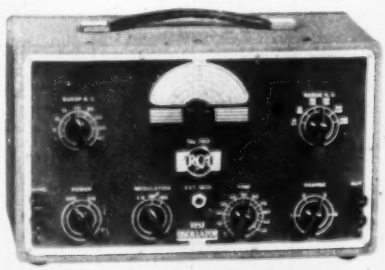


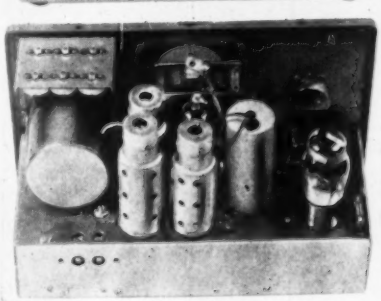
Portable Self-contained Immersion Pyrometer

New "Pyramid Pyrometer" for measuring temperatures of molten brass or aluminum is furnished with separate direct immersion base couples for brass and for aluminum. Thumbscrew adjustment on handled end permits convenient zero-setting before use to compensate for variable ambient temperature. Flexible end permits positioning thermocouple at any obtuse angle to rigid stem. Pistol-grip handle makes a natural hand hold and is so designed that operator holds it (and the reference junction) away from his body to bring dial in position for easiest reading. A hole in base of handle permits hanging pyrometer when not in use. *Tamms Silica Co., 228 N. La Salle St., Chicago, Ill.*

Oscillator for Cathode-ray Oscillograph

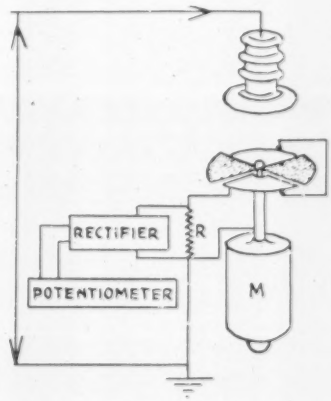
New No. 150 a-c. operated electronic sweep test oscillator is said to be suitable for every application requiring a wide frequency range. It may be used with all types of cathode-ray oscillographs in alignment applications, obviating the need for a separate frequency modulator, is particularly valuable in servicing receivers of the high-fidelity type having flat-top i-f. stages, which cannot be properly adjusted with an ordinary output meter. Output voltage 0.25 max. at all frequencies; output control 3-step attenuator plus continuously-variable adjustment; variable-width frequency modulation; sweep rate of 120 times per second; 4" dial, rotating 340° spreading the six fundamental frequency ranges over a total scale length of 45"; frequency range of 90-32,000 kc. Dimensions 13¾" × 9¼" × 7½". Weight 17 lbs. *RCA Parts Division, RCA Mfg. Co., Inc., Camden, N. J.*

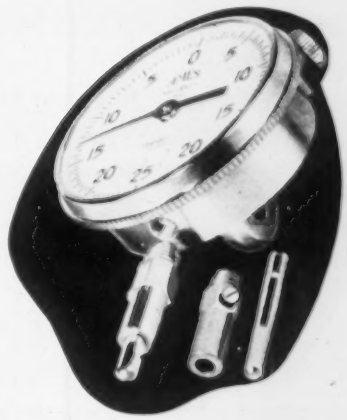




High-voltage Voltmeter

A generating type voltmeter, to measure high voltages in X-ray work without reaction on tube or equipment, draws no power from high voltage being measured and is said to represent a new principle. Operation: an insulator-supported electrode is connected to high voltage line; below electrode an armature in the form of a sectored disk, driven at constant speed by a synchronous motor, rotates immediately above stationary quadrants, which are grounded *via* a resistance. As armature rotates in the electrostatic field, charge induced on quadrants is alternately increased and decreased, and is transferred by way of the resistance. This constitutes an alternating current directly proportional to the potential of the electrode. Current is measured by rectifying potential drop across resistance, and measuring the resultant unidirectional voltage with a potentiometer. Housed in a movable cabinet 37" high, new voltmeter may be equipped with signals, automatic control or a recorder; is immune to disturbing electric fields; may be used for measurements on mechanical as well as tube rectifiers without special precautions, for "trouble-shooting," etc. Range of standard model is 0 to 100 kv. to ground, corresponding to 0 to 200 kv. in mid-point grounded systems. Limit of error is 0.8% of the range. For higher voltages it is incorporated into built-in high-voltage systems. *Leo Rehr, 12 Harvey St., Philadelphia, Pa.*





EASILY CLEANED

The case stem of the Ames Shockless Gauge can be easily unscrewed, the lower half of the spindle withdrawn for cleaning and the assembly replaced without otherwise disturbing the gauge. For details of other exclusive features, send for the Ames Gauge catalogue.

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Do you know your vacuum?

Let the TRU-VAC gauge tell you—accurately—continuously. Records pressures from 0—10,000 microns. Invaluable in processes requiring dependable knowledge of vacuum conditions.

Its numerous advantages are outlined in our bulletin TV2, gladly sent upon request.

CONTINENTAL ELECTRIC CO.

Geneva, Illinois

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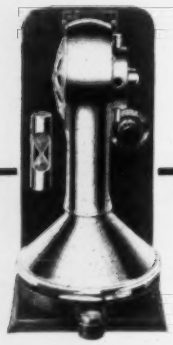

MOISTURE
Content by Drying

The Moisture Teller illustrated above will dry 50 gram test samples at the rate of one per minute. Test samples are weighed before and after drying to obtain moisture content in percentage.

Suitable for all granular, fabric, crystalline and fibrous materials.

Rapid and accurate moisture test for either laboratory or shop moisture control.

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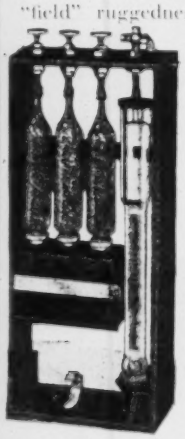
HAYS *Chemist's* MODEL
GAS ANALYZER
is Really Portable

Combines "laboratory" accuracy with "field" ruggedness and portability.



A 100 CC Orsat type analyzer with no fragile glass parts or delicate easily broken parts. Available in one, two, or three chamber styles for CO_2, CO, and O_2. Any desired scale range can be furnished. The operation is speedy and convenient. The pressed steel case is only 18¼ by 7⅞ by 4⅝. The weight of the three-chamber set, completely charged, is only 15½ pounds. Readings can be taken to 0.05%.

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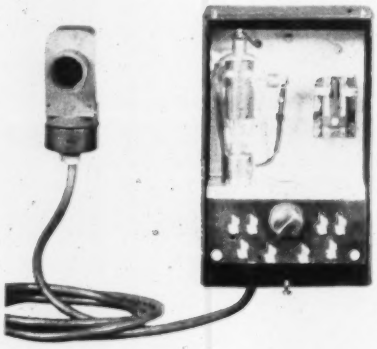
INSTRUMENTS MICHIGAN CITY, INDIANA, U.S.A.

Photoelectric Relays

Three additions to maker's standard line of photoelectric relays are said to be unique in that no amplifier tube is required. Impulse from phototube is impressed directly upon the grid of a 4-element inert-gas-filled "Thyratron" tube, which controls a magnetic contactor capable of making or breaking 35 amps. a.c. or carrying 10 amps. continuously. Speed: A light flash or interruption of 1/20 sec.



on 60-cycle power supply is sufficient to cause operation of the magnetic contactor. "Thyratron" tube conducts and thus energizes the magnetic contactor when the phototube is dark. Two of the relays can be so adjusted that 1 foot-candle illumination on phototube is sufficient to cause contactor to be de-energized and open its contacts. In the other new relay, only 1/10 foot-candle is required to cause contactor to open its contacts. In the magnetic contactor, elimination of flexible shunts assures long life; use of a metal panel and short leads results in freedom from undesirable effects of external electrical disturbances; the panel (illustrated) can be taken from its case by removing three screws. The type of "Thyratron" employed allows the use of these relays at ambient temperatures ranging from −20°C. to 50°C. Recent applications of these relays are said to indicate their practicability where slow light changes are encountered. This is a result of the snap action given the magnetic contactor by the sudden firing or cutting-off of the "Thyratron." *General Electric Co., Schenectady, N. Y.*

Car Ignition Tester

With this new Ignition Tester, it is said that "extremely accurate electrical tests can be made on the car battery,

generator, ignition cables, coil, condenser, spark plugs, lights, wiring, distributor cap and rotor, radio resistors, etc." Units mounted on the sloping panel consist of a voltmeter and milliammeter, both of the moving-coil type, Neon tube and adjustable spark gap assembly, selector switch and motor control rheostat on the front vertical panel are mounted a 6-volt motor-generator, with stroboscope breaker assembly, and a coil heater. The motor-generator is stable in operation, which makes it possible to test coils to the specification method. This unit supplies 500 volts d.c. for condenser tests. Operating instructions are furnished together with an "Allen Electrical Manual," and each purchaser is personally trained in the operation of the equipment by a factory representative. *—Allen Electrical Equipment Co., Kalamazoo, Mich.*

Automatic Intermittent Weigher-feeder

A new line of automatic "Precision Batch-Weighing Machines" incorporates a recent development of maker's "Vibra-Flow Feeders." Illustration shows new machine with the weighing hopper mounted on an even balance type of scale and fed from the main supply hopper through the medium of a "Vibratory Feeder Conveyor." The scale is equipped with two electrical controls: one cuts out the high speed feed through the conveyor when approximately 80% of the batch is weighed, the second stops the slow dribble feed of the conveyor when the exact weight is reached. Then the machine automatically dumps the weigh hopper and repeats the operation. Machine is available in various sizes according to batch

sizes required. It also is available with three different types of control: (1) With an automatic, electrically timed, continuous-repeating mechanism that will automatically weigh out batches and dump them so many times a minute; (2) Another design dumps the scale hopper automatically as soon as the batch comes to weight, repeating the procedure automatically; (3) Machine with means for manually dumping the hopper after inspection of weight. *—The Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.*

heories and Definitions of Hardness

Second instalment of "Hardness and Hardness Measurements." See page 1, Jan. 1937 issue.

By S. R. WILLIAMS
Professor of Physics, Amherst College

GENERAL CONSIDERATIONS

In what was for its time, and still is, a thought provoking article, Auerbach[1] discusses the question of "absolute hardness." The first part of the opening paragraph, as translated by Barus[2], is worthy of quotation. He says: "Hardness, aside from its practical importance, is one of the most remarkable properties of solid matter. This is shown at once by the difficulties which have been encountered in the endeavor to arrive at an accurate interpretation of it. Indeed, the attempts to solve questions relating to hardness are of very great variety, and are exceptionally large in number, and they have in a measure led to some interesting results; but the subject in its broader bearings has not been attacked with success, nor has a rigorous definition of hardness been established. Problems which present themselves in dealing with any of the physical properties of a body may usually be divided into three sub-problems: The first among these includes the scientifically exact description of the conception in question, so that the property may henceforth be treated as a purely mathematical variable. Then this quantity is to be measured, and methods and apparatus must be devised for that purpose. Finally, the measurements are themselves to be generalized by being extended to as many bodies under as many different circumstances as possible."

This may be summarized by saying that in the invention of any measuring device there are three distinct steps: (1) An idea or a theory, a mental picture of what is needed. (2) The actual development of a measuring instrument. (3) Widespread use of the instrument to show its applicability.

The forty-odd years since Auerbach wrote his paper has afforded many investigators the opportunity to carry out the third and last step suggested by him. The fact that we are not able to establish a reliable conversion table connecting 500-kg. Brinell numbers with 3000-kg. Brinell numbers is sufficient evidence that the absolute measurement of hardness is still a thing of the future.

HARDNESS DEFINED

In trying to arrive at a definition of hardness from the physicist's point of view, it may be well to consider some of the newer tools and theories which should have some bearing on this topic. The first great tool for studying substances in relation to hardness is the X-ray tube; and the first important theory is the electron theory of matter. This tool and this theory were not available to Auerbach forty-four years ago. Have they any contributions to make to our present problem? As Auerbach pointed out, one must in his imagination have a clear concept of what is happening before he can even begin to formulate mathematically the concept of which he is thinking. A preliminary definition of hardness has already been given as the resistance to penetration by another body. Given then a definite penetrator and a definite penetratee, what is it that penetrates what?

It must be admitted at once that in starting off in this fashion we are not starting *de novo* on the subject of hardness. Rather are we allowing ourselves to be biased by a point of view regarding hardness which has received considerable public recognition. However, if we know what we are doing, this preliminary definition of hardness makes a good point of departure for further discussion.

THE NATURE OF MATTER

There are three states of matter—gaseous, liquid and solid. In the discussion of hardness, attention will be paid to only one state, namely, the solid state. The very nature of the property of hardness would make this clear, although it is not always easy to distinguish between solids and highly viscuous liquids. For instance, what are tar and taffy, solids or liquids?

Both the electron theory of matter and a study of materials by X-ray analysis argue that our material universe is granular in its structure. It is composed of atoms. This applies to all states of matter. The formation of these granules into solid aggregates is brought about by the mutual attraction of these constituent particles. These forces of attraction are called adhesive forces when the particles are dissimilar and cohesive forces when they are similar. So long as these particles are not at the absolute zero of temperature, they may be thought of as being in a state of continual thermal agitation. The attraction between the constituent granules will be greatest at absolute zero, but will be diminished by the thermal agitation of the particles as the temperature rises. In general this will continue until the solid passes over to the liquid state.

When one body penetrates another there is a group of granules forcing themselves below the surface and in between the granules of the body being tested. In this process the distances between the constituent particles have been changed. Some have been separated and some have been pushed closer together. This has occurred both in the penetrator and in the substance penetrated. For the most part, the distance between the granules of the soft body has been changed more than in the hard one.

To get a clearer picture of this concept, recourse must be had to present theories of atomic structure and the positions which these atoms take in the solid aggregates as shown by X-ray analysis.[3,4,5] The kinetic theory of matter,[6,7] discharge of electricity through gases,[8] radioactivity,[9] magnetic phenomena,[10] spectroscopic evidence,[11] photoelectric phenomena,[12] and many other dis-

[1] E. Auerbach. Absolute Härtemessung. *Annalen der Physik und Chemie*, Vol. 43, 1891, pages 61-100. Ueber Härtemessung, insbesondere an plastischen Körpern. Vol. 45, 1892, pages 262-276. Ueber die Härte- und Elasticitätsverhältnisse des Glases. *Wiedemann's Annalen*, Vol. 53, 1894, pages 1000-1038.

[2] C. Barus. On the Absolute Measurement of Hardness. Smithsonian Report, 1891, Miscellaneous Documents of the House of Representatives, 1st session, 52nd Congress, Vol. 43, 1891, pages 207-236.

[3] G. W. C. Kaye. X-Rays, 4th Ed. Longmans, Green & Co., New York, 1923.

[4] W. H. & W. L. Bragg. X-Rays and Crystal Structure, 5th Ed. G. Bell & Sons, London, 1925.

[5] G. L. Clark. Applied X-Rays, 2nd Ed., McGraw-Hill Book Co., New York, 1932.

[6] A. D. Risteen. Molecules and the Molecular Theory. Ginn & Co., Boston, 1896.

[7] O. E. Meyer (translated by R. E. Baynes). The Kinetic Theory of Gases, Longmans, Green & Co., New York, 1899.

[8] J. J. and G. P. Thomson. Conduction of Electricity through Gases, 2 Vols., 3rd Ed. University Press, Cambridge, England, 1933.

[9] E. Rutherford, J. Chadwick and C. D. Ellis. Radiations from Radioactive Substances. MacMillan & Co., New York, 1931.

[10] E. C. Stoner. Magnetism and Atomic Structure, 1st Ed. E. P. Dutton & Co., New York, 1926.

[11] A. Sommerfeld (translated by H. L. Brose). Atomic Structure and Spectral Lines. E. P. Dutton & Co., New York, 1923.

[12] A. L. Hughes & L. A. DuBridge. Photoelectric Phenomena. McGraw-Hill Book Co., New York, 1932.

coveries are some of the important factors in leading to a unified picture of the structure of matter. This is important in understanding the property of hardness and the proper procedure for its measurement.

In the solid state the cohesive and adhesive forces are so strong that the atoms retain fixed positions relative to each other. This produces an aggregate which has and retains definite form. Resistance to change in form, *i.e.*, to change of relative positions of the atoms composing a body, may be defined as the rigidity of that material. The stress necessary to produce permanent deformation of the structure of the solid is most intimately allied to the property of hardness, for, in the measurement of hardness by a penetration method, it will be necessary to vary permanently these fixed positions which the atoms bear with respect to each other. It requires energy to alter these fixed positions.

X RAY ANALYSIS

Through the researches of von Laue[13] and the two Braggs[14], father and son, some definite conceptions may be obtained as to how the atoms are arranged in solid aggregates. By projecting X rays through crystalline media, these observers were able to show that the atoms

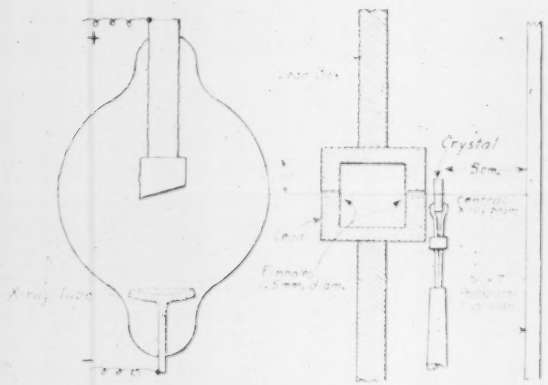


Fig. 3 Arrangement of X-ray tube, crystal and photographic plate for photographing von Laue's figures.

composing the crystal were arranged in a symmetrical order. In fact, it was this very orderliness of the atoms which made it possible to use a crystalline substance as a grating structure and learn not only the wave-length of the X rays used, but also the distance between the atoms. The pencil of X rays, in passing through the solid aggregate of atoms, arranged in orderly array, were diffracted by them. These diffracted X-rays produced diffraction patterns on the photographic plate set up beyond the crystal. See Fig. 3. From the photographic record on the plates produced by the crystal acting as a grating (see Fig. 4) the grating space or distance between the atoms could be determined. One of the crystalline media with which they first worked was ordinary cooking salt. NaCl is the chemical formula for salt or sodium chloride and it tells us that one atom of sodium joined to one atom of chlorine makes one molecule of salt. From the diffraction patterns, which they photographed, the observers of the crystalline diffraction of X-rays were able to build up a picture showing the arrangement of the sodium and chlorine atoms in the solid aggregate.[14] Fig. 5 shows a model of the arrangement of the sodium and chlorine atoms in simple order. In this graphical representation, black and balls are strung on a wire lattice. The white balls represent the sodium atoms and the black balls chlorine atoms. It was found that the atoms were ranged in a cubic lattice work with sodium and chl atoms alternating at the various corners of the cu The distance between the planes formed by this ord arrangement of sodium and chlorine atoms is 2.8 cm. which is of the same order of magnitude as are the diameters of the atoms themselves. Some substances take on one crystal form while others take on another. In Fig. 6 is shown a face-centered cubic crystal, while Fig. 6 represents a body centered cubic crystal. In the first an atom is at the center of each face, while in the latter an atom is found at the center of the cube itself. Iron, for example, possesses two modifications, alpha and gamma iron. Alpha iron has a body-centered cubic lattice; gamma iron a face centered one. The former is stable below 903° C. and also above 1400° C. up to its melting point, while the latter is stable only between these two temperatures. Figs. 7 and 8 and their captions will help to visualize these two states.

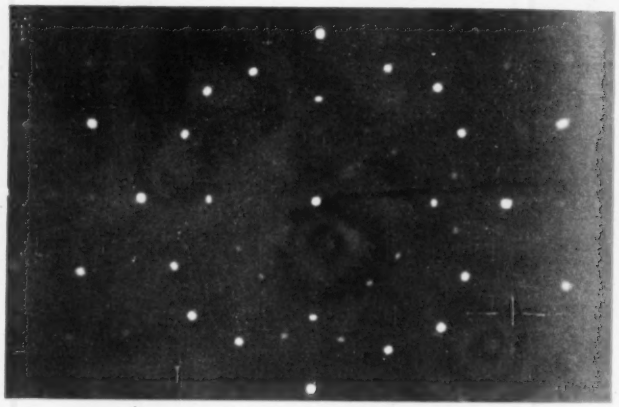


Fig. 4. Pattern produced on the photographic plate by the central and diffracted X-ray beams after passing through a crystal of rock salt.

Picture furnished by Dr. G. L. Clark, University of Illinois.

WHAT IS A MOLECULE?

One fact should be emphasized in considering Fig. 5. If the formula NaCl represents a molecule of salt, i composed of one atom of sodium and one atom of chlorine, the question arises which combination in Fig. forms a particular molecule of salt? Take any one atom of sodium and around it are eight chlorine atoms, any one of which could be the mate with which the sodium atom forms a molecule of salt. The point is, that in crystal solid aggregates the idea of a molecule has little or no meaning. We are dealing only with inter- and intra-atomic forces. These are the cohesive and adhesive forces about which we have been talking and in which we are concerned in this discussion. These forces of cohesion and adhesion are the most fundamental characteristics with which matter is endowed. In the use of a penetration method, the inter- and intra-atomic forces are the forces to be overcome in giving a permanent deformation. They form a part of the forces against which a penetrator must work when a penetration method is employed. Nor should one lose sight of the forces between the atoms of the penetrator in a study of hardness. Strains are set up between the atoms of the pene

[13] M. von Laue, *Physikalische Zeitschrift*, Vol. 14, 1913, pages 421-428, *Jahrbuch für Radioaktivität und Elektronik*, Vol. 11, 1914, pages 308-310.

[14] W. H. & W. L. Bragg, The Crystalline State, Chapters 3 & 4, MacMillan Co., New York, 1934.

...e as well as in the material penetrated. Most pene...tors are made either of steel or of diamond. Figs. 7 ...8 showed the arrangement of the atoms in the two ...ms of iron, while Figs. 9 and 10 show the arrange...t of the atoms in a diamond. These factors will be ...ussed later.

NONCRYSTALLINE MEDIA

In contrast to an orderly arrangement of the atoms ... a crystalline aggregate is the disorderly arrangement ...atoms in an amorphous substance like glass, fused ...uartz, or obsidian. From the standpoint of the physicist, ...e hardness of amorphous bodies is particularly inter...sting because neither the metallurgist not the mineralo...gist has been concerned with this class of bodies. Quartz is of interest because it is obtainable in both the crystalline (hexagonal) form and also in the fused or amorphous condition. It may be that glass in the amorphous state is in an unstable condition. With age it seems to go over into a crystalline arrangement. Not only has rubber peculiar elastic properties in the amorphous state, but on stretching and also on reducing to low temperatures it shows a distinct crystalline structure.

There is still a third class of substances which one interested in hardness should study. These are living substances, particularly plants, of which wood is a good example; the cellular structure of wood fiber is irregular and yet within the cell wall there is some degree of regularity to the arrangement of the atoms. Even in our finger nails there is some orderliness to the arrangement of constituent atoms, as shown by the fact that a beam of light passing through a finger nail becomes polarized.

These three fairly distinct types of materials, crystalline, amorphous, and nonisotropic, contain most of the substances in which hardness plays a rôle; and all three types of bodies must be considered in a comprehensive study of hardness of matter.

PHYSICAL PROPERTIES ALLIED TO HARDNESS

Also in this picture of solid aggregates comes the idea of *brittleness*. This relation has been brought out in an interesting way by Polyani.[1] "A solid body subjected to a mechanical load alters its form. If on removal of the load, the body returns to its original form it has been elastically stressed, but if a part of the deformation remains, it has been over-stressed." If a rupture of the whole occurs easily, the substance is said to be *brittle*.

Elasticity is that property of matter by virtue of which a material tends to recover its original shape and dimensions when the straining force is withdrawn. A body is perfectly elastic if the strain disappears when the external stress is removed. Under such conditions the strain is called "elastic strain."

Plasticity is that property of matter which allows it to be deformed into various shapes. A perfectly plastic material is one which can undergo an indefinitely large permanent deformation. The strain thus produced is called "plastic strain." Continuing, Polyani says, "Over-

[1] M. Polyani, Deformation, Rupture and Hardening of Crystals. *Transactions Faraday Society*, Vol. 24, 1928, pages 72-83.

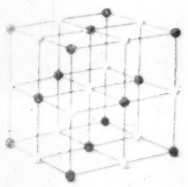


Fig. 5. Arrangement of sodium atoms (white balls) and chlorine atoms (black) in a crystal of ordinary salt: Simple cubic lattice.

Fig. 6. The arrangement of atoms (*a*) in face-centered cubic crystals and (*b*) in body-centered cubic crystal. In (*a*) there is an atom at the center of each face. In (*b*) there is one at the center of the cube.

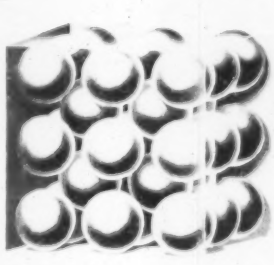


Fig. 7. Arrangement of atoms in a crystal of alpha iron: body-centered cubic lattice. In penetration methods for measuring hardness, these atoms are permanently pushed aside; and the way they are held together determines the hardness of the iron.

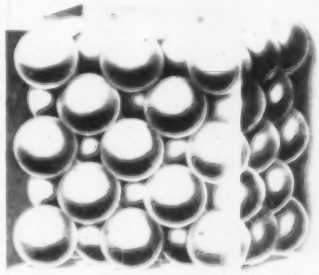


Fig. 8. Arrangement of atoms in a crystal of gamma iron. It has a face-centered cubic lattice. The forces between the atoms in this arrangement are different from those in the alpha form. Other factors being equal, the hardness of gamma iron will be different from that of alpha iron.

Courtesy Bell Telephone Laboratories.

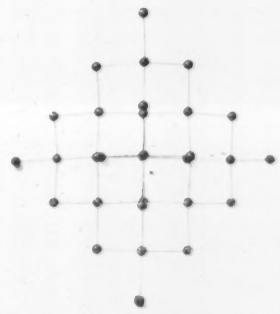


Fig. 9. Arrangement of carbon atoms in a crystal of diamond. Horizontal and vertical planes normal to page are (110) planes.

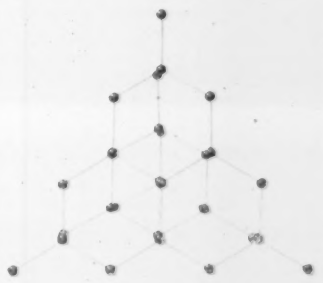


Fig. 10. Arrangement of carbon atoms in the diamond crystal. Horizontal planes normal to page are (111) planes.

(*Left*) Fig. 11. Balls piled in a cubic formation of closest packing (*b*). Attach one of the extra balls in (*a*) to each face of the tetrahedron in (*b*) and the face-centered cubic crystal unit in Fig. 12 is obtained.

(*Right*) Fig. 12. In the lattice on which crystals are built there may be found a unit cell which is then repeated throughout the crystal. This unit cell forms the crystal unit, which is the smallest piece of matter which can possess all the properties of a crystal. The above is a face-centered cubic unit.

stress may rupture the body or merely deform it; only when it is very brittle does rupture occur without previous deformation." This means that for brittle bodies the interatomic forces are relatively extremely small. Over against non-ductile or brittle materials stands that class of materials known as ductile bodies. Gold, silver, copper and mild steel are examples of matter which are capable of being drawn or rolled without actual rupture of the bonds between their atoms.

Creep of Metals. While the phenomenon of creep in metals at ordinary temperatures is negligibly small, it cannot be ignored in measuring the hardness of substances in which the creep effect is large. This property of matter and its relation to some magnetic properties will be discussed later.

WHAT IS A SINGLE CRYSTAL?

In looking at the structure of a crystal as in Fig. 5, one is led to ask, where does a crystal begin and where does it end? Polyani has answered this question in an excellent manner: "Since Laue's discovery of the diffraction of Roentgen rays by crystal lattices, the conception of a crystal and its structure has undergone a change in the mind of a physicist. When we speak today of a crystal we no longer think chiefly of the regular external forms, the crystal faces and edges, which formerly constituted for us the distinguishing characteristics of a crystal. The most important feature is rather the crystalline structure made visible by these phenomena of refraction; that regular arrangement of the atoms which we designate as the crystal lattice. When, for instance, a sphere or rod is turned from a cube of rock salt its crystal faces disappear, but since the sphere or rod has the same lattice structure as the cube from which it was made, we regard such a body as a crystal of rock salt and speak of it as a *monocrystalline body*." The paper[15] from which this is quoted should be read by those interested in this phase of the subject.

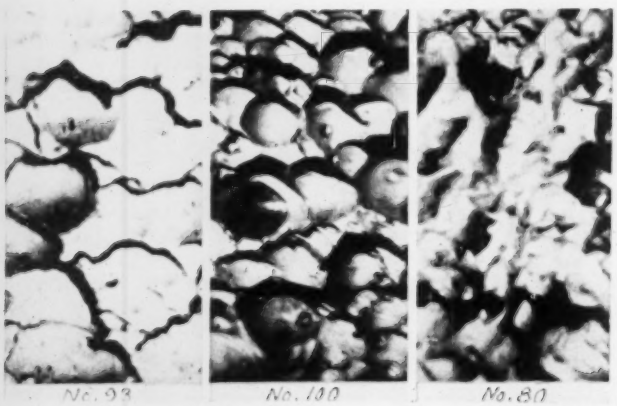


Fig. 13. Photomicrograph of grains in single crystals of silicon-steel, 3½% of silicon. In No. 93 the cubical grains have their surfaces almost parallel to surface of strip. No. 100 has them tipped up just a little more, while No. 80 has it almost equal to 45°. See Fig. 12.

Courtesy of Dr. Ruder, General Electric Co.

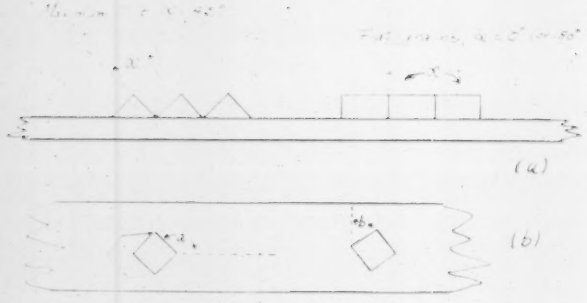


Fig. 14. This shows how the crystal units in Fig. 13 are oriented with respect to a strip of silicon steel as the single crystal is grown under a predetermined strain in a steep temperature gradient. The strips are about 25 × 1 × 0.1 cm. and constitute a single crystal.

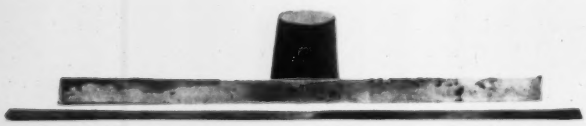


Fig. 15. Single crystals of silicon steel in the form of strips 25 × 1 × 0.1 cm.

Crystals furnished by Dr. Ruder of the General Electric Co.

In military reservations or navy yards, one often sees old fashioned cannon balls piled as are the balls in Fig. 11, b. The cannon balls are said to be in cubic arrangement of closest packing because the resulting volume per sphere is the least possible. If the four extra balls in (a), Fig. 11, have their nodules slipped into the proper place on each face of the tetrahedron composing (b), Fig. 11, there results the crystal unit shown in Fig. 12, which is one of closest packing to form the crystal unit of a face centered cubic unit. A comparison of Fig. 12 with Fig. 8 will show that the gamma iron crystal is composed of these units.

A polycrystalline body is one made up of an aggregate of monocrystals, the faces of the latter being turned in helter-skelter fashion throughout the entire portion of the polycrystalline structure. The crystalline structure of metals furnishes a good illustration of this sort. Fig. 13 is a microphotographic picture of an etched surface of silicon steel showing the arrangement of the crystal units in the structure as a whole. Fig. 14 furnishes an explanation of Fig. 13 while Fig. 15 is a photograph of a single crystal of silicon steel. Often there will be zones in a polycrystalline body in which a monocrystalline formation holds. This is shown in Fig. 16.

Continued on page 58

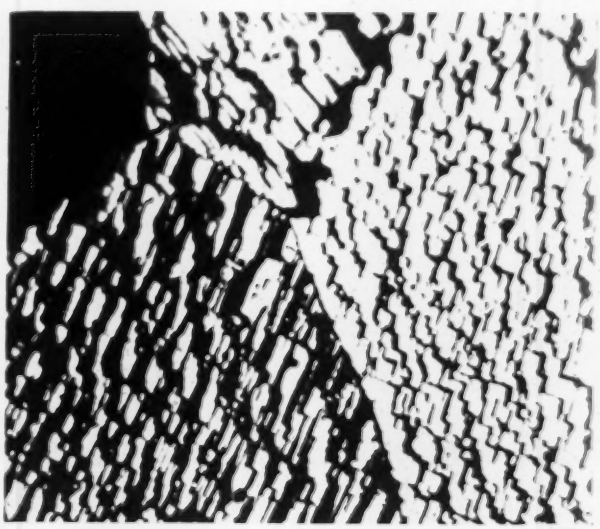


Fig. 16. A photomicrograph of the facets on a piece of silicon steel. Mag. 35×.

From Dictionary of Applied Physics by Walter Rosenhain. By permission of The MacMillan Company, publishers.

otes on Applications of Grid-controlled Gaseous Discharge Devices

By R. K. GESSFORD

Industrial Tube Division,
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

IN the last decade the application of grid-controlled gaseous discharge tubes has increased by leaps and bounds. The ability of these devices to out-perform mechanical relays in sensitivity, high speed of operation, durability as rapid-duty "contactors," and general adaptability for automatic operation, gives them an extremely wide applicability. In addition, gaseous discharge devices with thermionic cathodes always have a rectifying characteristic as a consequence of the asymmetry of the electrode properties. This characteristic permits of special applications which are altogether impossible with metal contact relays. The industrial instrumentation engineer, constantly on the lookout for ways and means of controlling and switching both large and small amounts of power more rapidly and effectively, finds many and varied uses for these tubes. Some of the more important industrial applications to which Grid Glow* tubes can be adapted are as follows:—

Production line control—Operation from the capacity or contact of objects in production line chutes.

Oil burner safety device—Operation from the conductivity of the furnace flame.

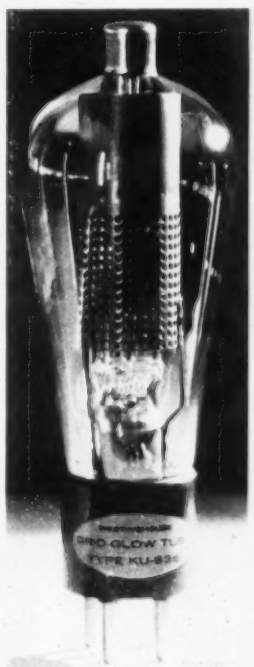
Phototube amplifier—Operating from the minute currents passed by a phototube.

Time delay relays—Operating from the slow change in voltage across a condenser in series with a high resistance.

Illumination dimming control—By the use of the tubes directly in series with the lights or by the use of a three-legged reactor saturated from the tube circuit.

Manual or automatic motor speed control—Operating from the variable field or armature voltage obtained by selecting by means of tubes, various fractions of each a.c. voltage wave.

Spot welder control—Operating by periodic switching of the a.c. supply by means of grid control of the tubes.



Readers of *Instruments* will think of many more. It is a purpose of this article to stimulate the extension of such industrial uses by presenting a general and then a specific discussion.

OPERATION OF GRID-GLOW TUBES

Grid Glow tubes are somewhat similar to vacuum tubes in that they have a cathode grid and anode, but they are radically different in characteristic because they are filled with an inert gas or mercury vapor. The conduction of current, therefore, is not by electrons from the cathode alone, as in the vacuum tube, but by electrons moving from the cathode to the anode and by positive ions moving toward the cathode. The presence of these positive ions prevents the formation of a space charge, which is found in vacuum tubes, and allows greater current to be passed through the tube with a low essentially constant drop just sufficient to ionize the gas.

A grid interposed between the cathode and anode of a gas or vapor filled tube will prevent an arc from striking between the cathode and anode if the grid is maintained at a voltage more negative than the critical grid potential.

When the grid potential reaches a critical value, the tube breaks down and current is conducted in the form of an arc. In this condition, the drop through the tube reaches a low and essentially constant value throughout the period of conduction. During this period of conduction, the space between the cathode and anode is filled with a plasma presenting positive ions and electrons in equal numbers, and the grid is no longer effective in controlling the discharge. The current to the anode is independent of the voltage on the grid and, with a negative voltage applied, a positive ion sheath is formed around the grid. Increasing the negative voltage merely increases the thickness of this sheath and, the outer edge of this sheath being at the same potential as the plasma, the potential on the control member cannot be felt beyond the sheath. The anode potential must then be interrupted, allowing the ions to diffuse and the sheath to disappear, thereby permitting the grid to regain control.

By using these tubes on alternating current at commercial frequencies, the anode voltage interruption or reversal is automatically present and grid control is regained every cycle.

If the potential applied to the grid is changed over the range given by the tube characteristic (see Fig. 1) the anode potential necessary to initiate an arc may be varied, so that on a.c. the point at which current starts to flow can be varied over the entire forward half cycle. As previously mentioned the current continues to flow until near the end of the cycle where it goes to zero and the grid regains control. If, therefore, the grid is so biased that breakdown occurs on a certain portion of the successive half-cycles, it appears as though the current has actually been interrupted although strictly speaking it is merely prevented from starting.

A grid controlled gaseous discharge tube which has a characteristic independent of temperature is an obvious improvement. In the case of a vapor filled tube the characteristic is greatly dependent on the operating temperature of the tube, but in one filled with an inert gas such as argon or helium the concentration does not vary greatly over the operating range and consequently the characteristic remains essentially constant. Fixed operation of apparatus is thus assured over extreme ranges of

*Westinghouse trade name for grid-controlled gaseous-discharge tubes.

ambient temperature with no other lag than the time required for the cathode to reach operating temperature. The advent of temperature-free tubes such as the new "KU-636 Grid-Glow" tube, with a negative control characteristic up to 750 volts peak and a sensitivity nearly equal to the mercury-vapor type, opens up a practically limitless field of possibilities. In the remainder of this article we shall deal specifically with this particular type.

The KU-636 Grid-Glow tube is a grid controlled device using a thermionic cathode, filled with helium at low pressure, and operating on the principle described in the preceding paragraphs. The fact that it uses helium and not mercury vapor as a medium of conduction renders it practically independent of shift in characteristic or tube drop. In this respect it is especially well suited for applications where the ambient temperature is subject to wide fluctuations. Its technical description, tabulated in the usual way, follows:

Number of Electrodes	3
Cathode Potential (volts)	2.5
Cathode Current (amperes)	7.0
Cathode Type	Oxide Coated
Cathode Heating Time (seconds)	10
Maximum Crest Inverse Anode Potential (volts)	750
Maximum Crest Forward Anode Potential (volts)	750
*Maximum Crest Anode Current (amperes)	0.3
*Maximum Average Anode Current (amperes)	0.1
Load Time Constant *T* (seconds)	30
Average Tube Drop (volts)	27.5
Maximum Overall Length (inches)	7
Maximum Overall Diameter (inches)	2
Base (Industrial) Bottom	No. 111
Base (Top Cap)	No. 3903
Type of Cooling	Air

*Two factors determine the current rating of Grid-Glow tubes: maximum electron emission of the cathode and the heat capacity of the tube parts.

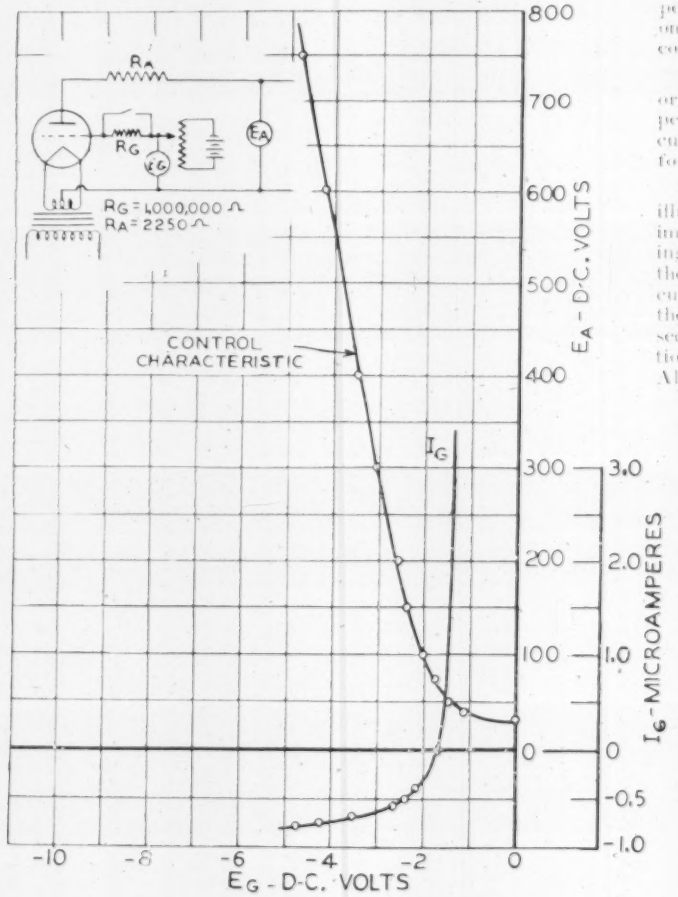


Fig. 1. Typical characteristic, KU-636.

It may be well at this point to define more fully the limits and ratings as given in the above tabulated description.

Maximum Crest Inverse Anode Potential is the highest instantaneous voltage that a gas- or vapor-filled tube will safely stand in the direction opposite to that in which it is designed to pass current.

Maximum Crest Forward Anode Potential is the highest instantaneous voltage that a gas- or vapor-filled tube will safely stand in the direction in which it is designed to pass current and with the control member adjusted to permit maximum anode voltage without conduction.

The two voltage ratings of the tube are determined by the following factors: (1) arc back, (2) grid control. Voltage peaks which exceed the value given for the KU-636, either in the inverse or forward direction, will probably diminish the life of the tube and must be guarded against.

Note—In circuits where oscillations are present, a special peak voltage measuring device should be employed to measure the crest value.

Maximum Crest Anode Current is the highest instantaneous current that a gas or vapor tube is designed to carry safely in the direction of normal current flow. This is determined by the maximum electron emission of the cathode, that is the maximum value of current the cathode can supply continuously for a short time without damage.

Maximum Average Anode Current is the highest value of steady direct current that a gas or vapor tube can safely carry continuously, or, if the current is rapidly pulsating, it is the maximum value of average current averaged over any period of *T* consecutive seconds (where *T* is the load time constant in seconds).

Load Time Constant of a gas or vapor tube is the specified period over which the anode current, regardless of wave form, is averaged.

The last three ratings can be illustrated as follows: The maximum crest anode current rating of the KU-636 is 0.3 amp., the maximum average anode current rating is 0.1 amp. and the load time constant *T* is 30 seconds. Then, under no conditions must 0.3 amp. be exceeded. Also, during no 30-second period, whenever taken, must the average tube current be more than 0.1 amp.

CHARACTERISTICS

The KU-636 temperature-free Grid-Glow tube is known as a negative control tube because the control or grid voltage is negative with respect to the cathode for all practical anode voltages. Less grid current is involved in the negative control tube, because with grid voltage negative with respect to the cathode and the tube non-conducting, the grid current is composed only of positive ions flowing to the grid and is extremely small.

The typical starting characteristic curve of the KU-636 is given in Fig. 1 and shows the relation between d-c. anode potential and d-c. grid volts, which characteristic is practically independent of temperature, taken with the circuit and constants shown at the top of Fig. 1. This curve gives the critical grid potential which will just prevent anode current passing for instantaneous anode potentials up to 750 volts which is the maximum crest forward anode potential rating of the tube. If the cathode is operated on d.c. instead of a.c., as shown, and the grid return brought to the negative end of the cathode, the characteristic will be shifted positively along the grid voltage axis. On the other hand, if the return is taken to the positive side of the cathode, the characteristic will be shifted in a negative direction along the grid voltage axis. The total shift between these two curves will be equal to the difference in potential between the two ends of the cathode. In the case where the return

n to either side of the cathode supply rather than center tap, the shift will be approximately equal to times the r.m.s. value of one-half the cathode voltage.

e grid control ratio is determined in the following manner: ke the portion of the curve between −3.0 and −4.5 volts The difference in anode potential between these two ts is 350 volts. Dividing 350 volts by the change in grid , 1.5 volts, gives about 230 as the grid control ratio. This remains fixed as long as the tube is operated on the ight portion of the characteristic, that is between 100 and volts d.c. Below this value the slope of the curve changes dly and consequently the grid control ratio follows in like nner, as can easily be seen by applying the same method of mputation. Fluctuations in the ambient temperature, having appreciable effect on operating characteristic, likewise have no ppreciable effect on the rid control ratio.

GRID CURRENT

The curve I_G shown in Fig. 1 is the typical value of instantaneous grid current for any KU-636 Grid-Glow tube. This is the instantaneous grid current at the moment the anode current is ready to flow, or, in other words, the grid current before breakdown. This is determined by taking the difference in grid potential, necessary to allow the tube to pass current, between $R_G = 0$ and 1,000,000 ohms over the operating voltage range of the tube.

The grid current at negative grid potentials with respect to the cathode is negative, for all practical anode voltages, as can be seen in Fig. 1 and consists of positive ions flowing to the grid. These positive ions are produced by collision between the electrons from the cathode and atoms of the gas. It may be likened to a saturation or leakage current. As the grid is made less negative the grid current diminishes, by reason of an increase in the rate of arrival of electrons to the grid, until a certain critical value of negative grid potential is reached at which there is no resultant flow of current to the grid. As the negative grid potential is further reduced, the effect of the electron current increases and the resultant grid current becomes positive, rising steeply. In this region, the electron current to the grid has completely overshadowed the positive ion current.

The maximum instantaneous grid current is determined in the following manner:

At a point on the typical control characteristic curve, drop a perpendicular to the grid voltage axis across this axis until the perpendicular intersects the grid current curve. The grid current as read on the Y axis for this point of intersection is the maximum instantaneous value of grid current before breakdown for the corresponding value of anode and grid potential.

As a rule the grid current during conduction is of little consequence, except it be limited to prevent heating of the electrode, and so it has not been plotted in Fig. 1.

RECOMMENDATIONS FOR OPERATION

The cathode of the KU-636 is of the oxide-coated type and must be run between ±5% of rated voltage. If the voltage is too low, a high tube drop results, which in turn causes bombardment of the cathode and a consequent loss of emission. If on the other hand the cathode voltage is too high, evaporation of the cathode takes place. In either case the characteristic is not seriously affected but the tube life is shortened.

Like other gas filled tubes, the KU-636 has no inherent current limiting characteristics and therefore a resistor must be used in series with it to avoid exceeding the crest current rating. This applies to the grid as well as the anode, and it is recommended that a series resistor of at least 50,000 ohms be used in the grid circuit.

The deionization period of the KU-636 is about 1 millisecond, so that the anode voltage must be zero or negative for this length of time in order that the positive ions may recombine and the grid regain control. This limits the usefulness of the tube to frequencies below 500 cycles. If the frequency is higher, the grid becomes ineffective in controlling the breakdown on the next positive half cycle.

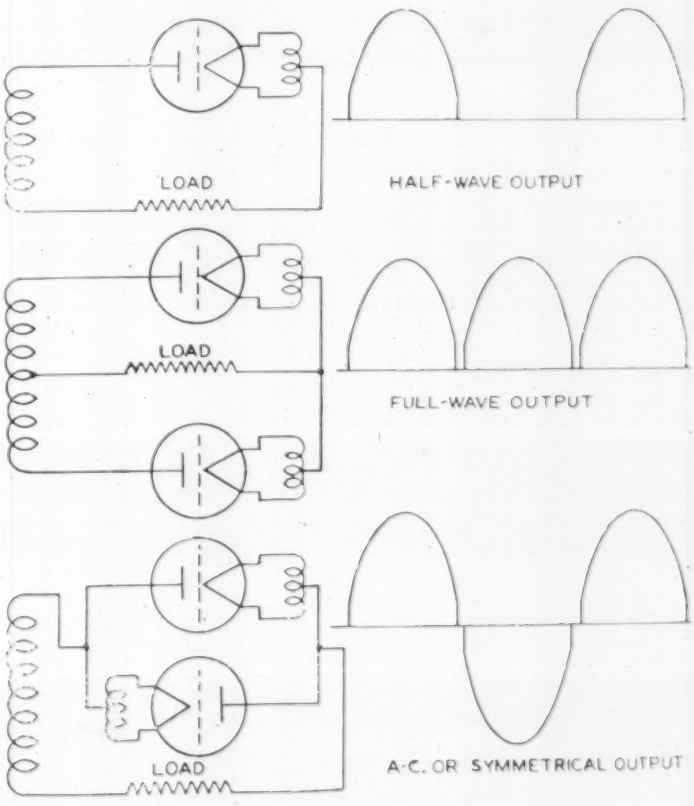


Fig. 2

The circuits shown in Fig. 2 are typical of those in which the KU-636 may be used. They are according to the output, half wave, full wave, and a.c. or symmetrical circuits. The output wave resulting from these circuits is shown for breakdown as early in the cycle as possible. This condition can be obtained only when the tube is used as a relay or as a straight grid controlled gas discharge tube.

As mentioned above, by controlling the point on the a.c. wave where the tube conducts and current begins to flow, the average rectified output of the tube may be varied.

Continuous variation of output current as a function of input may be obtained from the circuits in Fig. 2 by using phase shift or varying the voltage in the grid circuit, thus controlling the point on the cycle at which anode current starts to flow. Once started, the discharge continues for approximately the remainder of the half-cycle. If the tube is started earlier in the half cycle, the average current which flows is increased and so the output can be varied from essentially zero to a maximum value.

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Cathode-ray Oscillograph Applications

Excerpt as part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in the July 1937

By RALPH R. BATCHER

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MAGNETIC TESTS[1]

The method of utilizing magnetic tests for the determination of purely mechanical characteristics of ferrous products, in both mill and fabricated forms, has become standard not only in laboratories but in the test rooms of many factories. In such tests, however, the magnetic "history" of the specimens is of importance. With magnetic methods of analysis certain effects (appearing by reason of the extreme sensitiveness of the test apparatus) may indicate wide variations in the magnetic structure which have little effect on the mechanical properties. Equipment using the circuits hereinafter described will disclose any magnetic variations but it is beyond the scope of this article to show how the resulting oscillograms can be interpreted from the metallurgical standpoint. The oscillograph will not answer "yes" or "no" as to whether a given sample will have certain physical characteristics, but it will report instantaneously whether a sample has magnetic characteristics similar to a given standard, and it will do it without destroying the sample.

For any set of tests it usually is convenient to make a number of preliminary comparisons with differently treated samples representing known variations from the normal procedure, such as in the alloy content, or in the temperatures of tempering, quenching, annealing, etc. Standard reference oscillograms can then be made for future comparison with test records.

In this field the cathode-ray oscillograph plays an important rôle, inasmuch as a visual delineation of magnetic characteristics is so easily obtained. It possesses features not available with other types of oscillographs: daylight operation without hooded cover, simplicity and economy of operation, and ability to delineate a hysteresis curve without bringing in a time scale.

In many manufacturing processes, because of the simplicity of making such comparisons, visual checks of the magnetic properties can be made on every production item ("100% inspection") instead of on random samples only, to prevent defective pieces from receiving subsequent finishing operations.

Such tests may be divided into two classes: the study of permeability, coercivity, core loss, etc., to indicate expected operation in electrical equipment, and tests made to indicate some entirely different property, such as temper, hardness, alloy content, etc., or the existence of concealed flaws.

In the latter class, the usual test bears some relation to a study of hysteresis effects. An investigation of present practices discloses a wide variety of testing methods. For routine checks, samples are usually checked by a direct comparison with known standards, which eliminates a mathematical analysis of the curves. The operator soon becomes skilled in interpreting even minor varities of the curves, and with proper preliminary guidance he can judge whether such variations call for the rejection of the item. With some of these methods, little in the way of extra equipment (other than the cathode-ray oscillograph itself) is required.

DELINEATION OF THE NORMAL HYSTERESIS CURVE

As usual, the normal hysteresis curve is produced by plotting the relation between the flux density (as ordinates) and the magnetizing force (as abscissa). Several methods are available, by which the hysteresis curve can be delineated in its entirety. In the direct method, flux from the sample itself is applied to the neck of the cathode-ray tube, so as to produce a deflection in the vertical direction, as in Fig. 1a and 1b. The circuits also show the method of obtaining a horizontal deflection which depends upon the magnetizing force.

In using this method a number of errors are introduced, mainly due to the fact that the field is not constant across the space traversed by the electron stream. Since the axis of the cathode-ray tube is at a distance from the end of the specimen itself, the direction of the field will be at an angle from the axis of the core and so will have a component of force at right angles to the β or vertical direction.

In practice one may find a difference in the phase relation between the magnetization force and the potential that produces the horizontal deflection. These values must be in phase whatever connections are used. Fig. 2 represents several hysteresis curves of the same specimen with various such phase displacements. In this figure the true curve (0) and distorted curves obtained with various phase displacements are shown.

At higher frequencies eddy currents in the deflection plates may cause an additional error. With high magnetic intensities, if the deflection plates are of nickel (as common practice) the permanent magnetic charge induced therein will usually increase the distortion, so that plates of molybdenum, german silver, etc., are to be preferred. Or else, a circuit can be used, such as in Fig. 1c, wherein voltages induced in a search coil around the sample produce the vertical deflections. This method has the advantage of permitting the sample to remain at a distance from the cathode-ray tube; and at the same time it gives a deflection that is more nearly representative

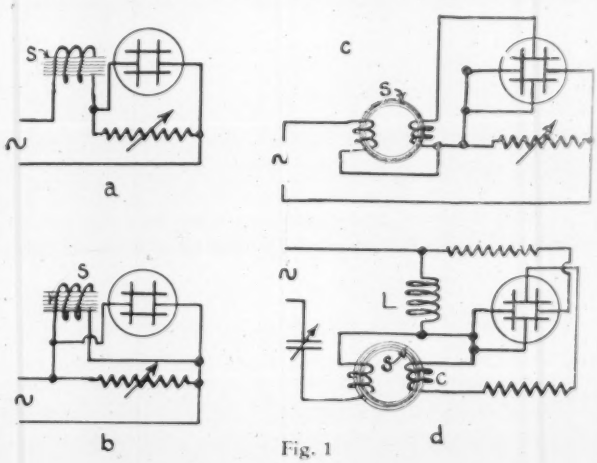

Fig. 1

[1]Angstrom. Über ein Objektive Darstellung der Hysterese Kurven bei Eisen und Stahl. *Physikalische Zeitschrift*, Vol. 1, 1899, pages 121-124.

[2]Knoll & Kleen. Kathodenstrahl-Oszillograph—Messung von Permeabilität, Dielektrizitaetskonstante, magnetischen und dielektrischen Verlusten. *Archiv für Technisches Messen*, Jan. 1934, page T14.

[3]Krüger & Plendl. Aufnahme von Dynamischen Magnet sierungskurven. *Archiv für Elektrotechnik*, Vol. 17, 1926, pages 416-421.

[4]Varley. Studies of High Frequency Magnetic Fields. *Philosophical Magazine, Series VI*, Vol. 3, 1902, pages 500-512.

[5]Steiner. Die Hystereseverluste. *Annalen der Physik, Series IV*, Vol 35, 1911, pages 727-754.

magnetization. However, with this circuit the vertical deflection is proportional to the *rate of change* of flux instead of being proportional to the actual flux density, and a pseudo hysteresis curve results. Actually, magnetic comparisons can be reliably made with these curves and so this system is frequently used.

In these tests, therefore, it will be necessary to discriminate between curves based on the rate of flux change, and those depending upon flux density. The former relation is equivalent to the differential curve of the latter.

Present steel testing methods in many laboratories are based on oscillograms obtained with the usual galvanometer type of oscillographs. Here the horizontal movement is always proportional to *time* and the curve is spread out on a linear base. A third system of measurements is then represented by the relation between the *instantaneous values of flux* and *time*.

A fourth method is the corresponding relation between the *rate of change of the flux* and *time*, wherein induced voltages in a pick-up coil are used to produce the vertical deflection.

Either of these methods can be duplicated with the cathode-ray oscillograph by the use of a linear time base. This apparatus may be either a synchronously motor driven sweep or the usual linear time base.

No important advantage is obtained with a linear time base, except in the cases where operators have previously become acquainted with methods using other types of oscillographs.

A fifth method comprises an arrangement whereby the flux from one sample is compared directly from or with that of another sample or a standard. Expressed as coördinates $y = \beta_a$ and $x = \beta_s$, where β_a and β_s are flux intensities of the sample and standard. With small samples this can be easily done by inserting the specimens into small magnetization coils affixed directly to the cathode-ray tube, care being taken that successive samples occupy the same position. When the specimens are alike, a diagonal line appears on the screen, but when magnetic differences are present this line is curved and often has loops appearing on it. Direct analysis of such curves is difficult, since neither ordinates nor abscissa follow a wave form that is known, but for routine inspection the method may be useful as a visual test.

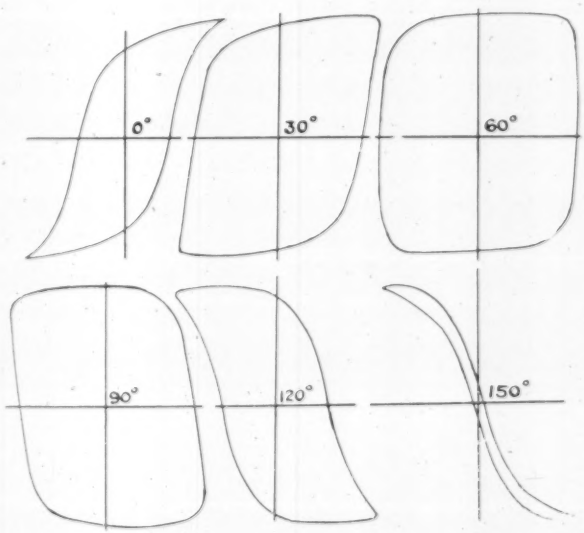

Fig. 2

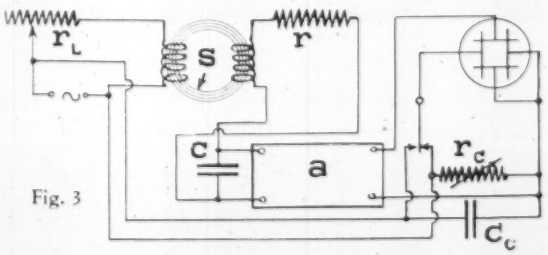

Fig. 3

A sixth method is that corresponding to the differential of the curve obtained from the last method, obtained in this case by the use of two similar search coils surrounding the sample and standard. Neither the fifth nor sixth method is important in practice, as other methods usually give superior results.

Of all the above systems, the easiest to set up are those utilizing the rate of flux change as obtained from search coils. However, if the required data can only be obtained from a true hysteresis curve, several purely electrical integrating circuits have been devised[6] to produce an integrated curve with methods that would normally produce deflections that are proportional to the rate of flux change. One of these circuits is shown in Fig. 3, the feature of which is the means of integrating, consisting in this case, of a resistance (r) and a capacitance (C), as shown. The resistance (r) is of sufficiently large value to make the voltage across the capacitor proportional to the magnetic flux. Due to the voltage lost in the circuit it is sometimes necessary to amplify the capacitor potentials as with an amplifier (a) to produce the required deflection. For studies at 60 cycles (r) can be about 25,000 ohms, and (C) about 10 mfd.

As before noted the deflection H must be correctly phased, so that the curve can be correctly interpreted. This can be done with some combinations of values C and r, in a phase-splitting circuit as shown.

A circuit which has been recommended for studies of hysteresis at high frequencies[7] is shown in Fig. 1d. The impedance of L is such that the voltage drop across it is about the same as across the search coil (s).

In practice, hysteresis curves have the same general appearance even though the characteristics of the materials and circuit conditions vary widely. Often small changes in the amplitude of the deflections, due to circuit adjustments unrelated to the magnetic circuit, obscure important variations in the curve itself. For this reason it may be desirable to superimpose two diagrams representing the sample and the standard, on the screen. This can be done by rapidly switching the two pickup coils, associated with the two specimens, alternately to the deflection plates.

The more usual arrangement makes use of a null method, where the flux from one sample is balanced against that from the standard, so that if the two are magnetically equal, no deflection occurs. One widely used system, which might be called the "differential difference" method, has been published by the A.S.T.M. based on tests by DeForest.[8][9][10] With the application of equivalent samples the resultant diagram is a horizontal line, or in any case can be represented by the equations:

$$y = d\beta_a - d\beta_s = e_a - e_s$$
$$x = dt \text{ or } dH$$

[6]Johnson, A Braun Tube Hysteresigraph. *Bell System Technical Journal*, Vol. 8, 1929, pages 286-308.

[7]Drysdale, Electrical Measuring Instruments. *Journal Institute of Electrical Engineers*, Vol. 65, 1927, pages 605-606.

[8]DeForest, Magnetic Tests of Tool Steel. *Transactions American Society for Testing Materials*, Vol. 23 II, pages 613-615.

[9]DeForest, Magnetic Tests. *Transactions American Society for Testing Materials*, Vol. 27 I, page 235.

[10]Spooner, Magnetic Tests. *Transactions American Society for Testing Materials*, Vol. 27 I, page 241.

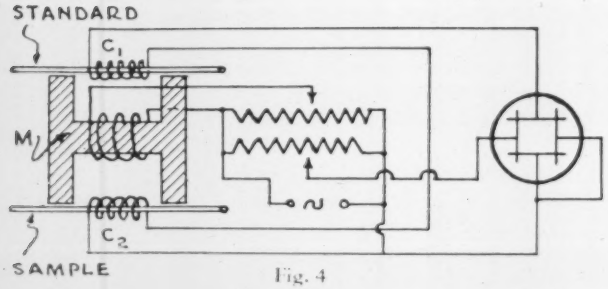

Fig. 4

Fig. 5

In this system a circuit such as in Fig. 4 is used. Fig. 5 shows oscillograms obtained in checking small samples of lamination stock in this manner. A heavy H-shaped core wound with 250 turns of No. 16 wire provides the magnetization force for both specimens when connected to an alternating current supply of proper voltage (4 to 10 volts). The samples are held firmly against the poles by brass rollers. Two pick-up coils each having 3000 turns of wire, are provided, connected series opposing. The horizontal deflection, which may be considered as representing H, is supplied from the same power supply, preferably through a phase shifting circuit. A straight line is delineated if the two specimens are alike. Variations in this set-up would permit continuous rolls of wire or cable or strips to be tested by pulling them past these poles.

Representative curves, Figs. 6a and 6b, obtained with this method will be considered. In each of these figures two hysteresis curves are shown together with a curve showing the resultant field (difference) and the total emf. of the two pick up coils connected in opposition. In these curves no phase difference occurs between the horizontal deflection potentials and the value of H. While undoubtedly a series of different diagrams are obtained when different steel samples are compared, these figures are difficult to analyze and bear but few distinguishing features by which various magnetic effects can be ascer-

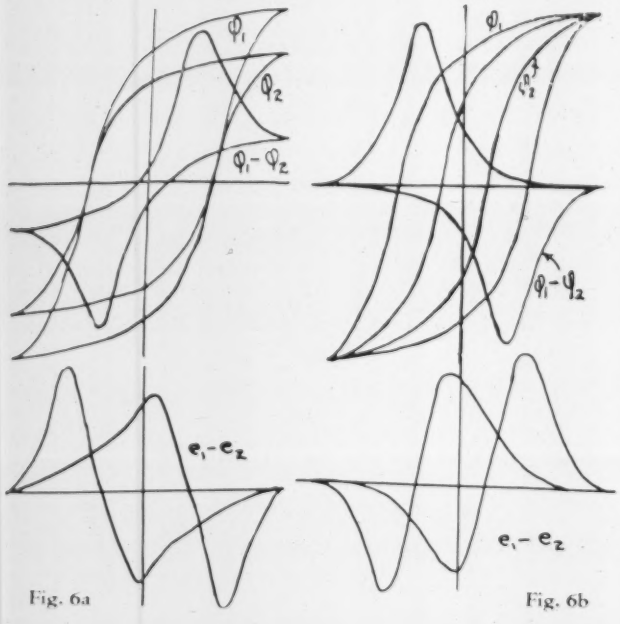

Fig. 6a

Fig. 6b

tained. For making tests of quantities of similar specimens, however, this test system is recommended as one that will most easily pick out those having unlike characteristics.

In reviewing these test methods it would seem that the last mentioned has certain advantages when a magnetic comparison with a standard is required. It is necessary, however, that the sample have the same dimensions as the standard, so that both are equally saturated. In Fig. 4 the degree of magnetic saturation of both is controlled by the voltage applied to the magnetization coil.

This test is also applicable to magnetic inspection of long strips, bars and wire of steels for either their magnetic characteristics or for homogeneity. The strip is drawn past the poles of this comparator and since adjacent portions of the strip are supposed to be identical, the diagram will be a horizontal line unless some magnetic discontinuity appears.

It may be desirable to place a narrow strip of opaque paper against the screen, to cut off this horizontal line so that no illumination is visible on the screen with equal specimens. An additional feature is a photocell alarm which indicates when the spot emerges from behind this mask. Another variation, which, however, requires a special tube, is to use a pair of metallic collectors in lieu of the screen inside the cathode-ray tube. These targets are connected to an alarm, through suitable amplifiers.

MAGNETIC COERCIVITY

It has been shown that the "coercive force" is an excellent test for knife blade blanks and other tempered pieces, both during the manufacturing process and on the finished article.

Since coercivity is read from a curve a simple instrument reading is not possible. In routine testing the blanks are applied to a set-up arranged to give the hysteresis curve. The actual amplitude of the B deflection is immaterial in the measurement of coercivity and as it is not necessary that the entire hysteresis curve be centined to the screen the vertical deflection can be increased so that it will cross the H axis more nearly at right angles, permitting the coercivity to be read with accuracy.

Nearly all types of tempered tools such as drills, chisels, etc., can be similarly tested. The advantage of these tests is that the tools are not damaged by the test, nor is the surface marred.

MAGNETIC COMPASS[11,12]

In using a cathode ray tube to replace the magnetic compass needle, important advantages are apparent: instantaneous response, and immunity from effects of tilting or rapid swings, such as are encountered on an aircraft. The low deflection sensitivity of present tubes is the main limitation found.

If more sensitive tubes* can be made available, the amount of auxiliary equipment needed is quite small, only a power supply. Since greatest sensitivity is obtained with low anode potentials, this supply may be

Continued on page 60

[11]Bruche. Magnetic Compass. *Teknisk Tidskrift*, Vol. 61, 1931, page 157.

[12]Knipp & Welo. Measurement of the Earth's Field. *Philosophical Magazine, Series VI*, Vol. 32, 1916, page 381.

*There is no lower limit to the anode voltage that can be used, except that arising from space charges around the cathode. The limiting factor is the fluorescent sensitivity of the screen which has a definite threshold effect, that is, no visible fluorescence is noticed below a certain low electronic velocity. See references 13, 14 and 15:

[13]Bruche & Ende. Fadenformige, Sichtbare Electronstrahlen. *Zeitschrift fur Physik*, Vol. 64, 1930, pages 186-190.

[14]Buchta. A Low-Voltage Oscillograph. *Journal Optical Society America*, Vol. 10, 1925, pages 581-590.

[15]Farnsworth. A Method of Obtaining Intense Beams of Slow Electrons. *Journal Optical Society of America*, Vol. 15, 1927, pages 290-2

Oscillography

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By PERRY A. BORDEN and M. F. BEHAR
Member A.I.E.E. Editor, *Instruments*.

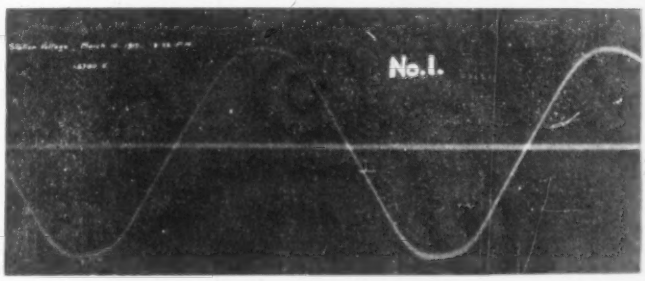
(*Continued from page 50*)

6. Electromagnetic Class

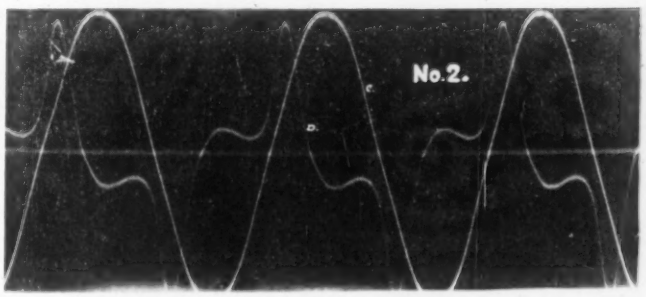
(*Concluded*)

(d) Typical Applications

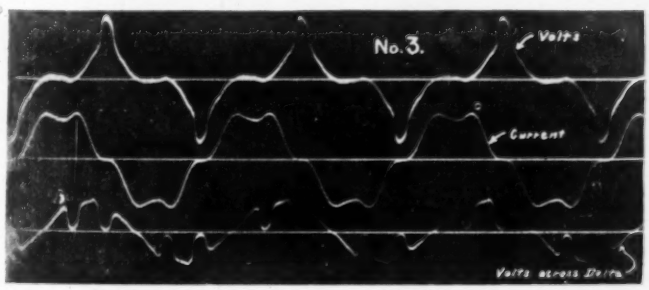
The fourteen small oscillograms reproduced herewith represent investigations in several electrical fields made by one of the authors at various times in the past twenty-five years. While these were all produced with one of the earlier types of electromagnetic oscillographs, they serve to indicate the versatility of the instrument, making it apparent that the possibilities of the more modern forms with their improved automatic accessories are limited only by the imagination and the ingenuity of the user.



No. 1 is a simple representation of the voltage of a commercial a-c. supply and serves to indicate the closeness with which the true sine wave may be approached in actual practice.



No. 2 shows two waves, one approaching in form the true sine wave and representing the voltage of an a-c. supply, the other being a distorted voltage obtained from the same supply through a "freak" system of transformer connections. The third harmonic, frequently found in circuits associated with ferromagnetic systems, is present to a marked degree.



No. 3 illustrates other voltages and currents in the same hook-up as that upon which No. 2 was obtained. Records show that this particular arrangement was an attempt to produce triple frequency from a system of transformer connections having no moving parts.

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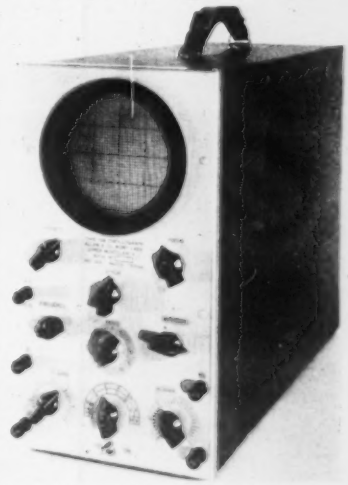

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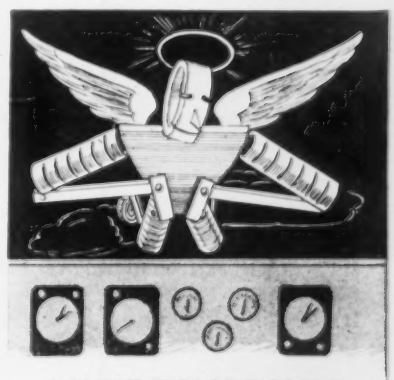

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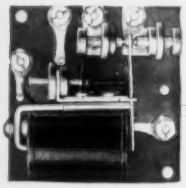
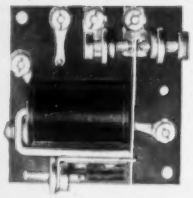


2C



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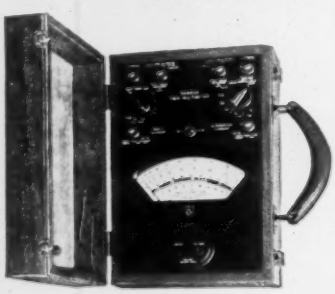

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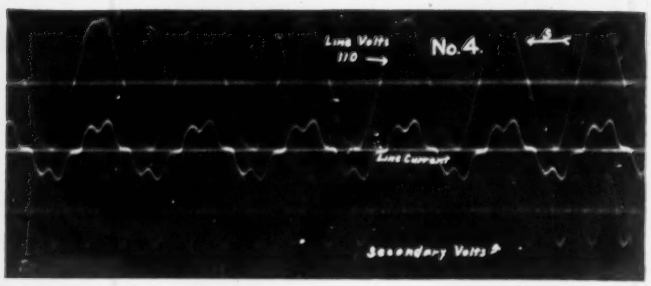
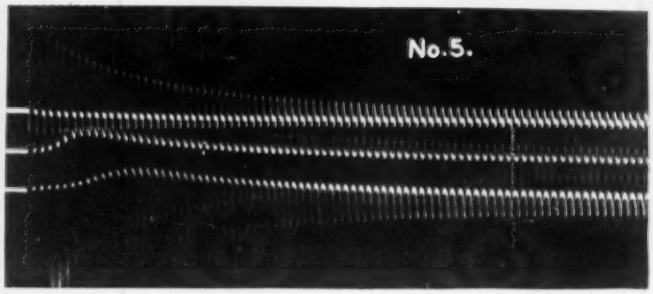
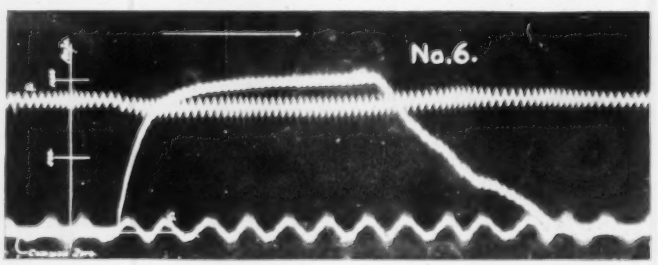


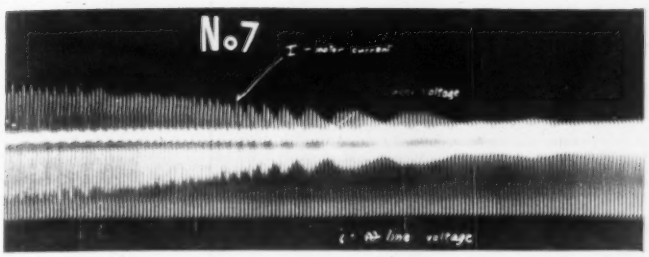
No. 4 shows the over-all results obtained with the above test. The upper waves represent the normal frequency supply voltage and current, and the lower wave the output voltage of triple frequency. The practical use of frequency-changing apparatus of this nature is generally restricted by the limitation of low efficiency, poor regulation and low power factor.



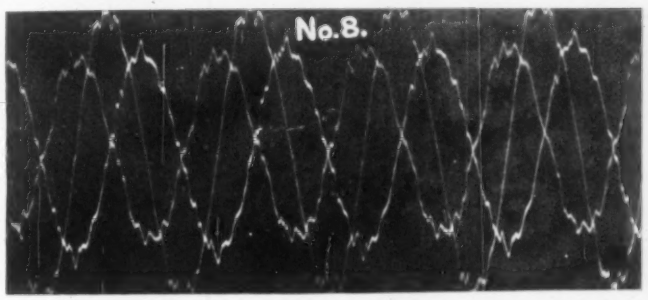
No. 5 represents the rush of current upon first cutting in a three-phase bank of large transformers. It will be observed that the nature and the extent of the "overshoot" differ in the three lines. As the initial rush of magnetizing current is subject not only to the point on the voltage wave at which the circuit is closed but to the point at which it was previously opened, successive random "shots" are not likely to reproduce performance. Some modern oscillographs are equipped with accessories whereby the circuit under test may be repeatedly opened and closed at any desired instant in the cycle.



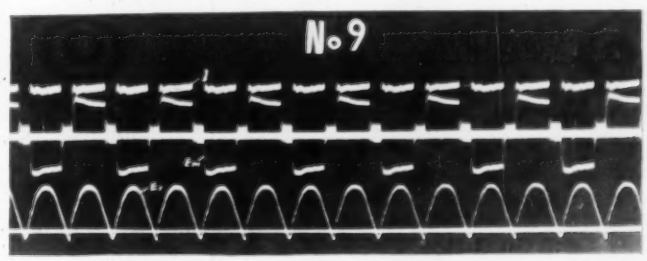
No. 6 shows a short circuit on an electric railway system. The low frequency wave at the bottom shows for timing purposes the 25-cycle voltage supplied to the converter feeding the system. The commutator voltage is shown by the rippled line running along the upper part of the film. The zero of this voltage wave coincides with that of the a.c. voltage, but the scale is much larger. It will be observed that a triple-frequency component of the original voltage exists in the d.c. output of the machine. This test was made by closing the circuit breaker on the short-circuited line and allowing it to open automatically. The growth of the current is plainly seen, it having reached an almost steady value when the breaker operated after a lapse of seven cycles of the supply voltage. The decline of the current to its zero value after the opening of the breaker occupies a little over four cycles. This film is not shown as an example of ideal circuit breaker operation, but solely with the object of demonstrating the usefulness of the oscillograph. The exposure is part of a test made in 1916; and since that time vast improvements in circuit breaker design have been effected.



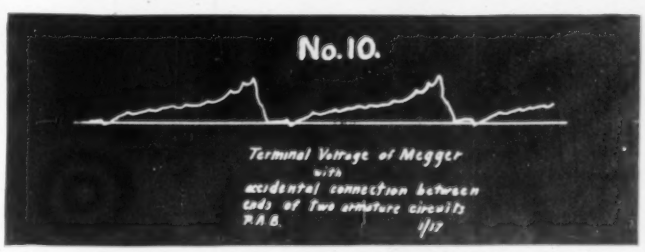
No. 7 shows currents and voltages in a small self-synchronizing motor generator set thrown directly on a 60-cycle supply. The surging of current as the incoming machine approaches synchronism is distinctly apparent.



No. 8 shows respectively, terminal voltage, the voltage of one coil, and the star voltage, of an old alternator. "Tooth ripples" are distinct. Compare these waves with those shown in films No. 1 and No. 2. There are few present-day installations where such a voltage wave would be tolerated.



No. 9 represents a test on a small vibrating inverter supplied from a 60-cycle circuit through a copper-oxide rectifier. At the bottom of the film is shown the rectified voltage, and the current taken from this supply is represented by "I". "E_m" shows the "alternating" voltage derived from the inverter. As such units are generally supplied from a d-c. source, this could hardly be considered a fair test. In any case the use of suitable filter circuits enables such devices to provide an output voltage of reasonably good wave-form.



No. 10 suggests the usefulness of an oscillograph in general repair work. The generator in a "Megger" insulation testing set (See *Instruments*, March 1934, page 54) has four distinct armature windings normally cut in series by a special commutator. It should deliver direct current with a negligibly small ripple. The wave-form shown is from a Megger having an accidental interconnection between two of the windings.

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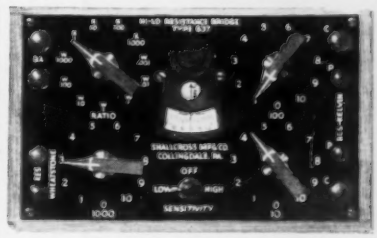

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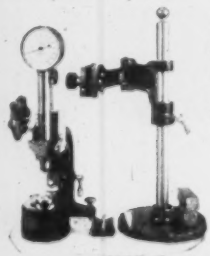

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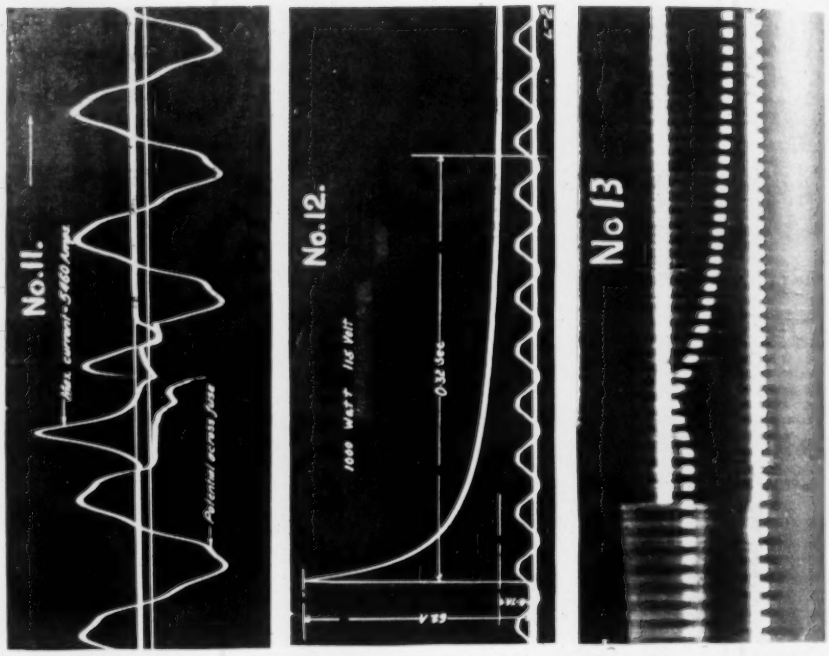
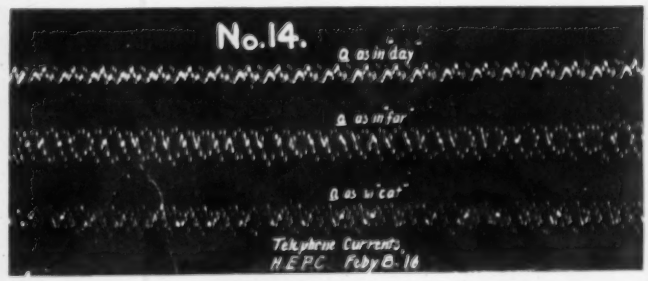


No. 11 represents a test on a high-voltage fuse. Two fuses were placed in series on opposite sides of a circuit and a breaker closed between them. The change in voltage and the rush of current are well shown. It will be noted that the arc was ruptured in one cycle.

No. 12 illustrates the initial rush of current through an early form of gas filled tungsten lamp, rated at 1,000 watts, when switched on a d-c. circuit. The 25-cycle timing wave shows that 1/3 second was required for the current to decline to its steady value from its initial peak of nearly eight times normal. As the initial rush of current due to the relatively low resistance of the cold filament is subject to many variables, there is a wide divergence in the starting characteristics of different types and sizes of lamps. This may be looked on as an extreme case.

No. 13 shows values obtained in a test on a hydro-electric generating unit, and represents the result of expedients necessitated by the limited number of vibrators available in the older form of oscillograph. Two vibrators (the upper and the lower) were required for recording necessary values in the test, leaving only one of the three free for providing data on speed and gate opening. A circuit was made up to pass through the middle vibrator a small direct current controlled by a potentiometer type of rheostat mechanically linked to the turbine gate. Thus the deflection of the light spot was made representative of gate opening. In series with this circuit was placed a contactor interrupting the current twice for each revolution of the turbine shaft. A voltage derived from a standard electrically-maintained tuning fork was superimposed on the wave, thus establishing a reference frequency. In the oscillogram, the gate opening is represented by the height of the broken line above its zero, while half-revolutions of the machine are indicated by the breaks in the line. Standard time intervals, as derived from the fork, are traceable as a ripple appearing throughout the length of the line, and easily counted on prints from the original film.*

* P. A. Borden, Determination of Rotational Velocities, *Electrician* (London), Vol. 97, 1926, pages 722-723.



14 shows wave forms in a telephone circuit corresponding to three nciations of the vowel "a." In the two decades that have elapsed since lm was made, sound investigation has become one of the important fields cillography; and instruments designed for this special purpose provide ductions far more readable and precise than that shown in the illus-

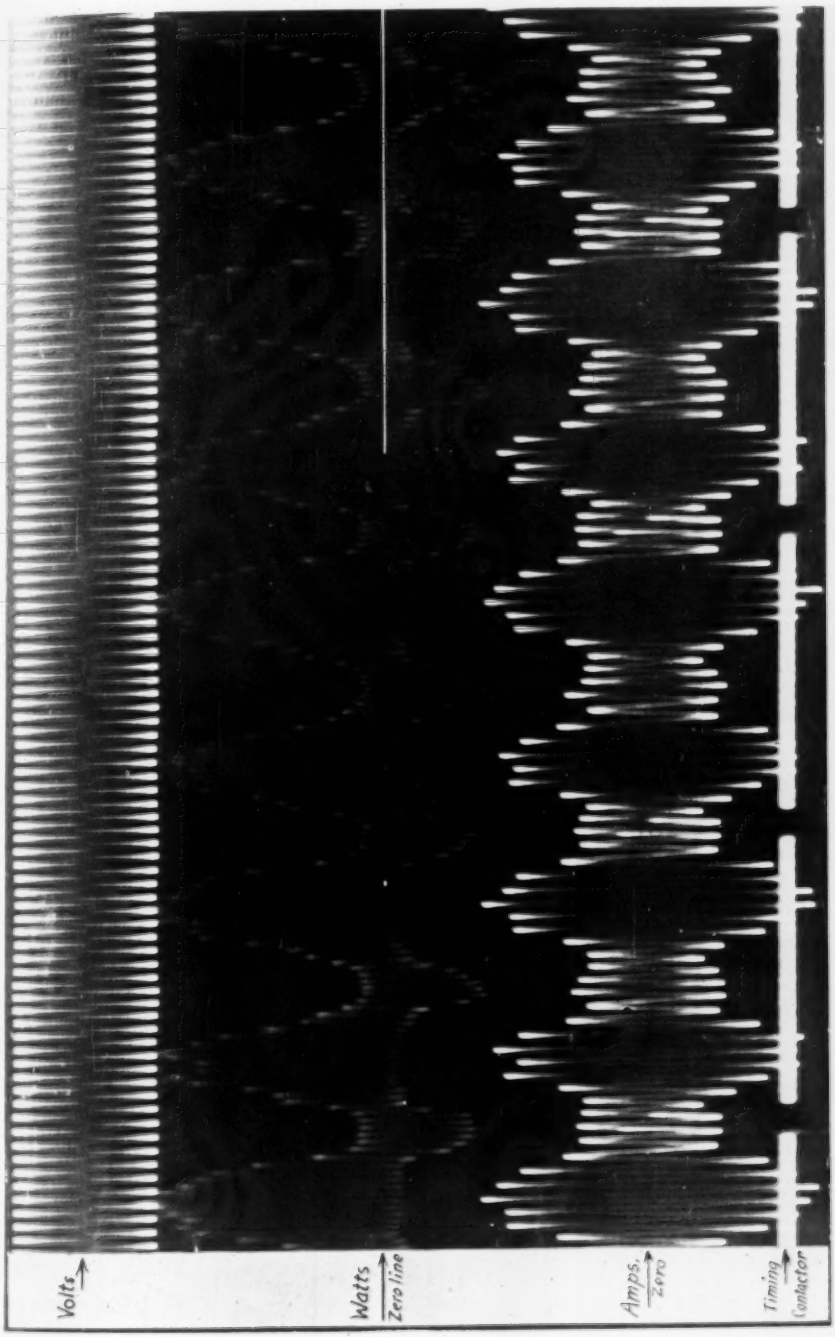


Fig. 49-38

The usefulness of the electromagnetic oscillograph in machine design is suggested by the records shown in Fig. 49-38, which represents a test on a metal-working machine having heavy reciprocating parts. The upper curve shows the 60-cycle voltage supplied to the motor driving the machine, the lower a-c. curve the current drawn, and the middle curve the watts consumed. The bottom line shows the action of a contactor used for definitely timing the performance of the machine. It will be observed that with each cycle of operation the power flow actually reverses, indicating that the inertia of moving parts was sufficient to feed energy back into the line at certain intervals in the operating cycle, giving a labored action. Improvements in the mechanical proportioning of the parts made it possible to eliminate the extreme fluctuations in power flow, with a resulting improvement in performance.

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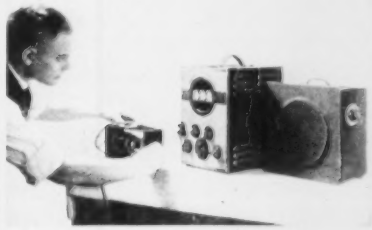

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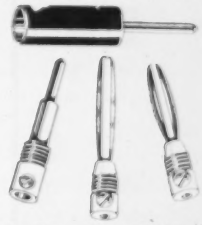

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PROBLEMS — SOLUTIONS — DISCUSSIONS

PROBLEM No. 2
(As published in December issue)

Consulting engineer advises us that he will pay $10 (in addition to our $5) for a solution acceptable to him of the problem of measuring moisture in wet and dry "glue pearls" or "pearl glue" by a RAPID method. Present method—oven drying of pea-like samples—is too slow in view of introduction of modern continuous drying process of manufacture. Ideal would be a continuous indication. Next best, a method taking a minute or so.

SOLUTION
By PHILIP EWALD

The method described herein depends on variation of the glue's electrical resistance with moisture content. It is intermittent, requiring a few seconds for each measurement. The test points shown in Fig. 1 are inserted into the glue sample, preferably into a section freshly cut with a razor. The moisture content is

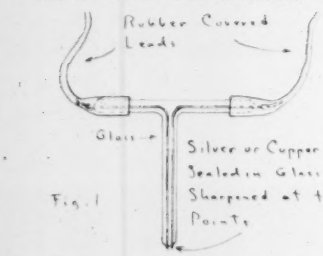


Fig. 1

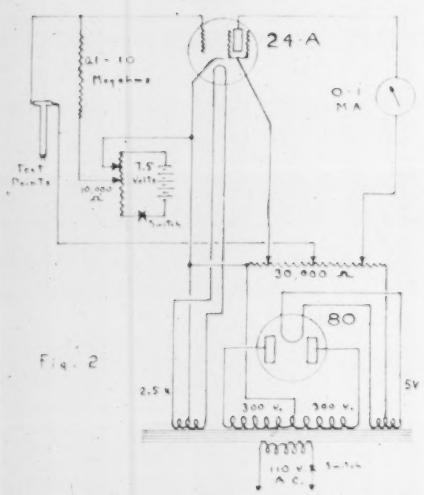


Fig. 2

then read directly from a calibrated milliammeter in the circuit shown in Fig. 2.

Construction of the test points is self-explanatory. The electrical circuit is essentially a vacuum-tube voltmeter, though its use is simpler. Resistance values shown are only approximate, would have to be determined by trial. The parts of the entire outfit would cost less than $15.

SOLUTION
By L. R. KETTENRING

A moisture meter for grain, now on the market, can be altered and calibrated to measure the moisture content of any substance which, in a dry state, is a non-conductor of electricity. The usual pearl glue is such a non-conductor. The moisture meter for grain consists of an electrical instrument indicating the electrical resistance between two crushing rolls which are insulated from each other and rotated at slow speed by an electric motor. For various classifications of material, the spacing between the crushing rolls is adjustable, and a contact dial is arranged to provide a direct indication of moisture content of the material crushed between the rolls.

Adaptation of this instrument to pearl glue would require scrapers to clean the rolls of glue that might cling during the crushing process. It would be necessary also to calibrate the instrument for that particular class of service by running several precision oven determinations.

A continuous indication could be provided by by-passing a small portion of the pearl glue into the rollers for crushing and testing. A continuous record could be obtained by the use of a potentiometer recorder in place of the indicating instrument.

SOLUTION
By ROBERT E. TOZIER

Although there are several possible attacks to the problem, the one I believe offers about the best chance of working out in practice is based on the change of electrical resistance with moisture content. This method would have to be adapted to the conditions present at the point of measurement; for example, should the glue sample be taken where it is quite wet, an ordinary conductivity bridge would furnish sufficient accuracy, but if quite dry, the sample would probably have to be tamped between electrodes, and either a d-c. bridge method or the neon glow lamp flicker frequency used for determining its resistance.

DISCUSSION
By MAURICE J. BREVOORT

The water content of glue can be determined by either chemical or physical means. A determination by evaporation is an example of the former method; a determination of plasticity an example of the latter.

A sample placed in concentrated acid will give up its water to the acid and the heat of dilution or the hydrogen-ion content will be a measure of the water content. The plasticity will be a direct measure of the water content of the sample. The determination of the plasticity may vary from a viscosity measurement at one extreme to a [illegible] test at the other, depending on the [illegible] ness of the sample. If the sample [illegible] spherical or can be made spherical [illegible] the rate of flattening under pressure [illegible] the percent of rebound from a fall [illegible] be used as a measure of the water [illegible] tent. If the sample is irregular, the [illegible] of extrusion through an orifice [illegible] constant pressure will determine the water content. It is probable that these tests must be made under well-controlled conditions of temperature and humidity.

DISCUSSION
By E. I. WENGER

Three suggestions are offered; any of the required operations could be performed in a minute or less:

(1) Burn a specified weight of pearl. Proportional weight of ash may give a close approximation of moisture content; this proportion would be highest in the case of samples initially "bone dry."

(2) The electrical conductivity would probably be an invariant function of the moisture content (at any particular temperature).

(3) The specific gravity of the pearls would probably be related to their moisture content.

SOLUTION
By H. OLKEN

There is a commercially available device the size of a table radio and utilizing a "radio" principle which instantly gives direct readings of moisture content of the material contained in a glass test-tube, as shown in Fig. 1. It requires that the test-tube be filled nearly to its top

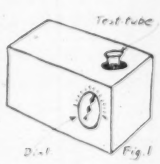
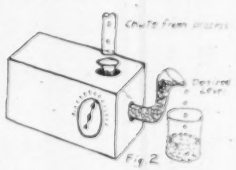


Fig. 1



which precludes the possibility of measuring the moisture in a single "pearl" of glue. It also requires, of course, initial calibration for the class of material, such as cereals, soap chips, granular or flaked food products, etc. It is being used satisfactorily on the products mentioned, also on some colloids.

Moreover, this instrument may be modified to measure continuously the moisture in a continuous sample (see Fig. 2), the chief requirement being that the "pearls" should not cohere and clog the glass tube. The continuous indication will then serve as a guide for the manual control of the process by the operator; but it is easy to conceive a further modification involving (a) continuous recording on a chart and (b) automatic control of the process, just as is done in recording and controlling pH.

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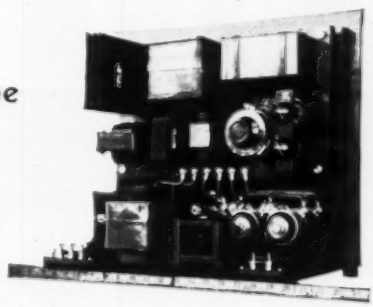

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THEORIES AND DEFINITIONS OF HARDNESS

Continued from page 44

In the case of a single-crystal the faces of the crystal units composing the complete crystal will all be oriented in the same way. These angles which the facets form with the surfaces and axes of a single crystal strip are designated by the angles, a, a, and b as in Fig. 14. These angles may be measured by an optical goniometer which is shown in use in Fig. 17 where a single crystal wire is under measurement. Inasmuch as iron comes into prominence in hardness testing a photomicrograph of [illegible] iron is shown in Fig. 18. Fig. 19 shows another [illegible] crystalline structure, that of a zinc alloy. The average size of the grains in one specimen—depending on its composition and previous treatment—may be as small as 0.01 mm. or as large as 0.20 mm.

To be continued

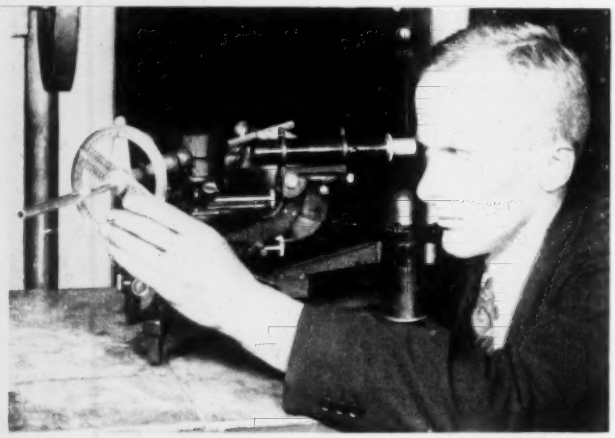

Fig. 17. By the reflection of light rays from the facets of the crystal units the orientation of a single-crystal may be determined.

Courtesy of Bell Telephone Laboratories.

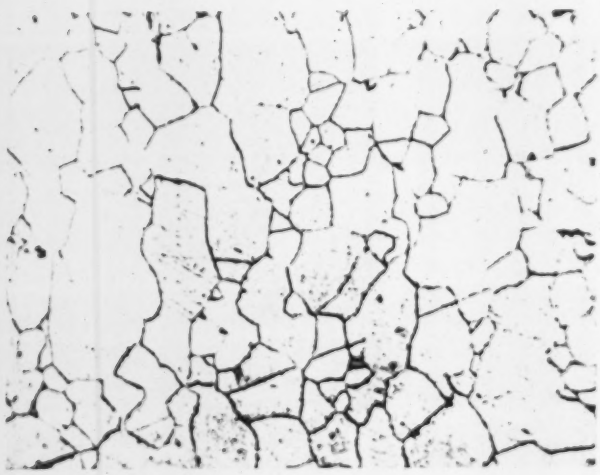

Fig. 18. A polycrystalline structure of pure iron. Mag. 150×.

From Dictionary of Applied Physics by Walter Rosenhain. By permission of The MacMillan Co., publishers.

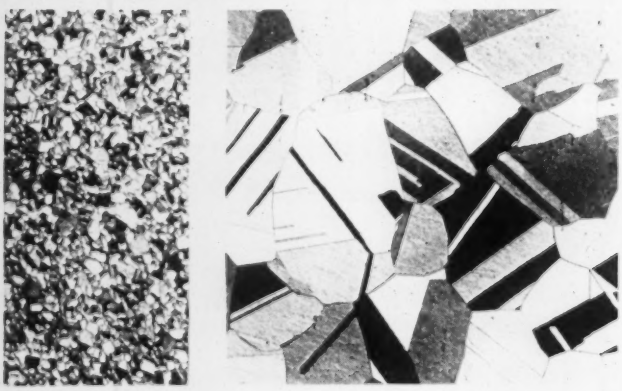

Fig. 19. Polycrystalline structure of 70-30 copper-zinc alloy. Each grain may be considered as a monocrystalline structure.

Courtesy of The American Society for Testing Materials.

CATHODE-RAY TUBE APPLICATIONS

Continued from page 50

obtained entirely from batteries, or from a small spark coil operating on batteries. The variable potential obtained from such a source has the advantage that the spot appears to the eye as a radial line which provides an excellent "pointer." The calibration is not affected by changes in the battery potentials.

The magnetic field of the earth acts on the ray directly throughout the whole length of the tube, eliminating all need for deflecting plates. The conditions therefore are unlike most other applications; since here an amplifier cannot be utilized to increase the sensitivity. Either a long tube must be used or else a shorter tube with a small screen, augmented with a suitably placed magnifying lens. The tube is mounted vertically in any case, with the compass card affixed to the screen (Sept. 1935 article, page 244). It may be of interest to note that the earth's field will normally deflect the ray toward the east. This field, while not of equal intensity over the earth, has a value of the order of 0.2 gauss.

In an investigation of the practical utilization of this application, the writer used a gas-focused tube approximately thirty inches long, operated with a pulsating voltage of 500 volts (max.) on the anode. A special focusing arrangement was necessary to secure focusing at a range of anode potentials. Deflections of three inches were discernible before the radial line faded out during each cycle, as the anode voltage dropped below about 300 volts.

To be continued

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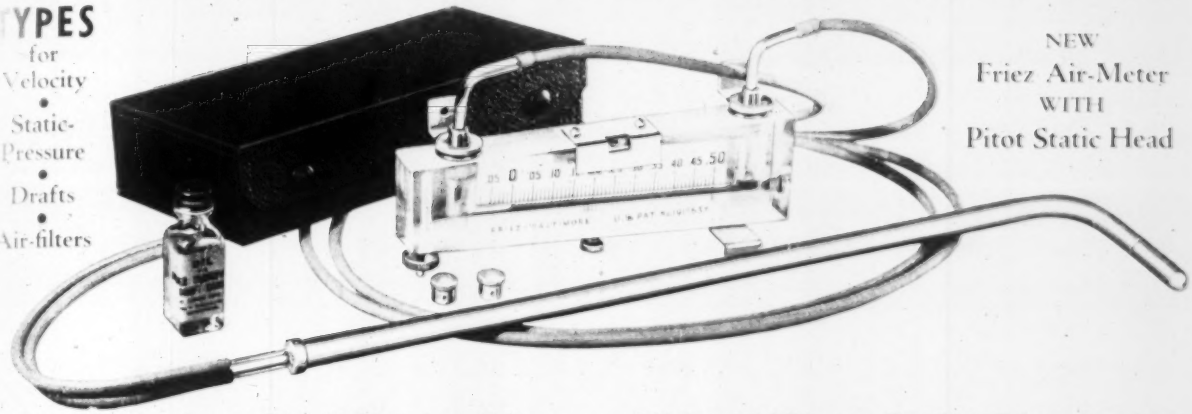

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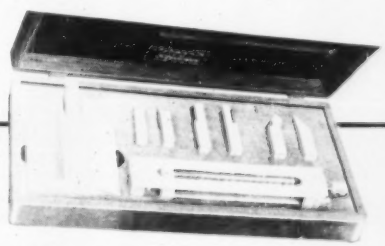

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